UNIVERSITY OF SOUTHAMPTON

FACULTY OF MEDICINE

Cancer Sciences Unit

Volume [1] of [1]

Presentation of patients with right iliac fossa pain – factors affecting the diagnostic pathway and evaluation of a clinical decision support tool.

by

Katherine Lucy Pearson

Thesis for the degree of Medical Doctorate

June 2018

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF MEDICINE

Cancer Sciences Unit

Thesis for the degree of Medical Doctorate

PRESENTATION OF PATIENTS WITH RIGHT ILIAC FOSSA PAIN – FACTORS AFFECTING THE DIAGNOSTIC PATHWAY AND EVALUATION OF A CLINICAL DECISION SUPPORT TOOL

Katherine Lucy Pearson

Right iliac fossa (RIF) pain is the largest source of acute referrals to the general surgical take. Most previous studies concentrate on retrospective analysis of patients who have had an appendicectomy. This study has two aims. The first is to investigate the factors affecting the diagnostic pathway of all patients referred with RIF pain. The second is to implement and evaluate a clinical decision support tool (CDST) integrated into a specific RIF pain clerking proforma.

All patients over the age of 15, without a previous appendicectomy, who were referred acutely to the general surgeons were eligible for the study. Data was collected prospectively on all patients during initial, pilot and implementation stages.

605 patients were included in the study. 292 patients were included in the evaluation of the clinical decision support tool. The majority of patients presenting with RIF pain do not have appendicitis. The most frequent diagnosis is non-specific abdominal pain. Use of the CDST significantly improved the agreement of the senior clinician plan with that of the junior clinician's plan ($p=<0.0001$). There is no change in the frequency of imaging requests with the CDST but the proportion of CT scans being requested by junior clinicians is significantly increased ($p=0.0342$).

This study provides new and updated information on the factors affecting the diagnostic pathway of patients presenting with RIF pain. It is the largest study to look at this cohort and is more applicable to current practice than the previous studies. The implementation of a novel CDST has been shown to significantly improve the decision making of junior clinicians when used within a specific RIF pain pathway. Further work needs to be done with a larger study to look for further improvements to the diagnostic pathway and to understand and improve the poor uptake by junior doctors.

Contents

Table of Tables

Table of Figures

Table of Figures

Table of Figures

List of Accompanying Materials

Case report form

Right Iliac Fossa Pain Clerking Proforma with Clinical Decision Support Tool

Academic Thesis: Declaration of Authorship

I, Katherine Lucy Pearson

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

Presentation of patients with right iliac fossa pain – factors affecting the diagnostic pathway and evaluation of a clinical decision support tool

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signed:

Date: 03/06/2018

Acknowledgements

Many thanks to:

Miss Karen Nugent for her supervision, encouragement and overall unwavering support.

Professor Tim Underwood for general supervision and support.

Professor John Primrose for general support and encouragement.

Mr Ian Bailey, Mr James Kirkby-Bott, Mr Vas Trompetas for support within the Acute Surgical Unit and facilitation of this project.

Dr Henry Pearson for technical skills in designing the clerking proforma on Adobe InDesign, statistical support and proof reading.

Mr Rahul Sreekumar for statistical support.

Mrs Natalie Chand for proof reading and general support.

Mrs Helen Harrison for IT system and clerking proforma details and support.

Dr Cath Grierson and Dr Charlie Lane for information and help regarding radiological imaging aspects.

Mr Iain Anderson and the Association of Surgeons of Great Britain and Ireland for the opportunity to contribute to the Emergency General Surgery Commissioning Guide (Right iliac fossa pain section) as a result of expertise gained from undertaking this thesis.

Definitions and Abbreviations

ANP	Advanced Nurse Practitioner
ASU	Acute Surgical Unit
BMI	Body Mass Index
CDST	Clinical decision support tool
CEPOD	Emergency Operating Theatre
Cochrane	Cochrane Library including Cochrane reviews
CRF	Case report form
CRP	C-reactive protein
CST	Core surgical trainee
CT	Computerised tomography scan (abdominopelvic)
CTKUB	Computerised tomography (kidney ureter bladder)
DOH	Department of Health
ED	Emergency Department
eDOCS	University Hospital Southampton electronic patient documents system
EGS	Emergency General Surgery
eQUEST	University Hospital Southampton electronic patient investigation requesting and reporting system
ERGO	Ethics and research governance online (University of Southampton)
FF	Free fluid
FY	Foundation Year (doctor)
GCP	Good Clinical Practice
GI	Gastrointestinal
GP	General Practitioner (Primary Care)
HICCS	Electronic operation note system
IBD	Inflammatory bowel disease
IBS	Irritable bowel syndrome
ICNARC	Intensive Care national audit and research centre
IRAS	Integrated Research Application System
iSurvey	University of Southampton online survey software
ITU	Intensive Therapy Unit
JAC	Electronic Prescribing System
LOS	Length of stay
McBurney's point	Point on the right side of abdomen that is located one third of the distance from the anterior superior iliac spine to the umbilicus
MRI	Magnetic resonance imaging
MS	Medical student
MSK	Musculoskeletal
NAD	Nothing abnormal described
NAR	Negative appendicectomy rate
NEJM	New England Journal of Medicine
NELA	National emergency laparotomy audit
NHS	National Health Service
NICE	National Institute of Clinical Excellence
NPV	Negative predictive value
NSAP	Non-specific abdominal pain
PACS	Electronic radiological imaging viewing software
PPV	Positive predictive value
PV	Per vaginal
R&D	Research and development
RCS	Royal College of Surgeons of England

RIF	Right iliac fossa
SBO	Small bowel obstruction
SHO	Senior House Officer
STI	Sexually transmitted infection
StR	Specialty Registrar (doctor)
UHS	University Hospital Southampton NHS Trust
UK	United Kingdom
USA	United States of America
USS	Ultrasound scan
UTI	Urinary tract infection
WCC	White cell count
24/7	24 hours a day and 7 days a week

Chapter 1 Introduction

1.1 Aims

The aims of this study are to

- Investigate local and national diagnostic methods for patients presenting to the adult general surgical take with right iliac fossa pain.
- To develop risk stratification tools for this cohort of patients to allow improvement of the patient pathway.
- To design, implement and evaluate a right iliac fossa pain clinical decision support tool integrated into a right iliac fossa pain admission pathway.

1.2 Overview

Emergency general surgery is the highest-volume surgical specialty and continues to increase in clinical activity annually (1). It has been identified by the Royal College of Surgeons and the Department of Health (2,3) as needing dedicated attention to improve patient care and outcomes. Historically it has lacked comprehensive research compared to the elective specialties. Approximately 530, 000 patients present acutely to the surgical take every year in England (4) ranging in severity of pathology. Mortality rates in patients undergoing emergency laparotomies admitted to ITU has been shown to be 25% and intensive care costs are more than £88 million annually (5). Outcomes for emergency surgical patients vary widely across the country shown by the wide confidence intervals associated with ICNARC data (5). National focus has been on the 'High Risk' surgical patients undergoing laparotomy, via the National Emergency Laparotomy Audit (NELA) (6) however this represents only a small percentage of the admissions to the acute surgical unit. In the 2011 report, 'The Higher Risk General Surgical Patient', The Royal College of Surgeons and the Department of Health stated, as their first recommendation, that trusts should create formalised pathways that all emergency general surgery patients should follow including a clear diagnostic and management plan (2).

Right iliac fossa (RIF) pain is the most common presentation to the acute surgical take (7,8) and appendicectomy is the most common emergency surgical operation (9,10).Therefore any improvement in the pathway for this cohort of patients will have a proportionally large impact on emergency general surgery overall. This is the rationale for undertaking this study.

Common pathologies causing RIF pain include appendicitis, acute gynaecological pathology (ovarian cyst rupture, mid-cycle pain, tubo-ovarian sepsis, ovarian torsion), diverticulitis, renal calculi and mesenteric adenitis. A significant proportion of patients presenting with RIF pain are discharged with a diagnosis of NSAP (11). The pathologies underlying RIF pain range in severity and the need for intervention. Both diagnosis and management can be complicated, particularly with atypical presentations of the causative pathologies. General surgical literature looking at RIF pain is predominantly concerned only with appendicitis and is often retrospective, identifying those patients who have had an appendicectomy and examining the diagnostic process prior to theatre. This has been identified as a flaw and the need to examine all patients with RIF pain has been highlighted (12). This study looks at all patients presenting with RIF pain, follows them prospectively and considers all eventual diagnoses.

1.3 The right iliac fossa

1.3.1 **Anatomy**

The right iliac fossa forms the lateral wall of the greater or false pelvis which is superior to the superior pelvic aperture. It contains the caecum, appendix, the right ovary and fallopian tube in women and can contain part of the sigmoid colon.

1.3.1.1 The appendix

The vermiform appendix is a vestigial organ present only in humans, certain anthropoid apes and the wombat (13). It is a blind muscular tube with mucosal, submucosal, muscular and serosal layers attached to the caecum inferior to the ileocaecal junction at the convergence of the taenia coli. The position is variable but the majority of the time it is retrocaecal (14).

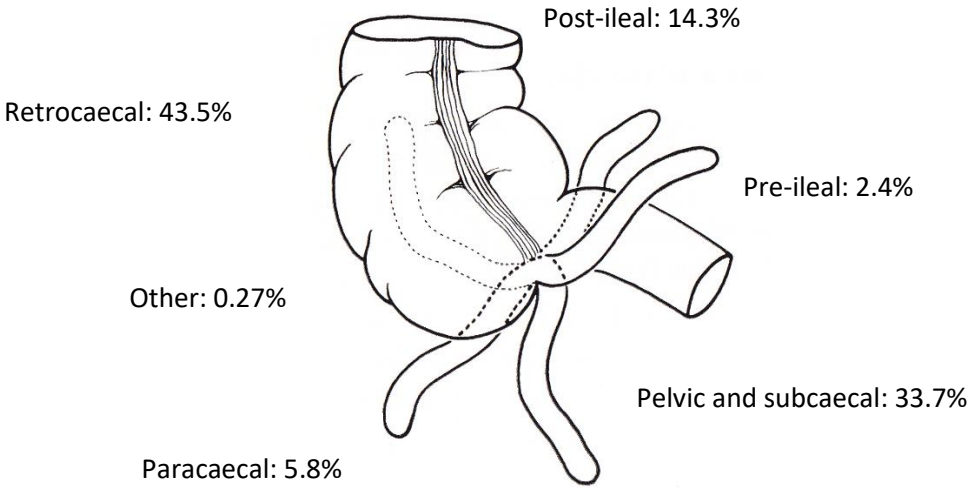


Figure 1 Variable positions of the appendix - adapted from de Souza (15)

De Souza et al looked at 377 adult cadavers to establish the data in Figure 1. They also summarised the data from 16 other studies which showed a wide variation in frequency of appendiceal position but consistently retrocaecal, pelvic and subcaecal position were the most common (15).

The appendix contains approximately 200 lymph follicles in the submucosa; they decline in number with increasing age (16). The blood supply to the appendix is from the appendicular artery, a branch of the ileocolic artery and venous drainage is into the ileocolic vein. The lymphatics run in the mesoappendix down to the ileocolic lymph nodes and then to the superior mesenteric lymph nodes. Sympathetic and parasympathetic nerves from the superior mesenteric plexus supply the caecum and the appendix (14).

1.3.1.2 The right ovary

The right ovary is a gland positioned close to lateral pelvic wall, attached to mesovarium of the broad ligament. The ovarian vessels, lymphatics and nerves are contained within the suspensory ligament of the ovary. Arterial supply is via the ovarian arteries, directly from the aorta. Venous drainage is via a pampiniform plexus that gives rise to the ovarian vein. The right ovarian vein ascends to the inferior vena cava. The lymphatic vessels follow the blood supply and drain into the lumbar lymph nodes. The ovary is innervated by nerves from the ovarian plexus. The parasympathetic fibres are derived from the vagus nerves (14).

1.3.1.3 The caecum

The caecum is the first part of the colon and sits between the terminal ileum and the ascending colon. It gains its arterial supply from the ileocolic artery, a branch of the superior mesenteric artery and is drained by the ileocolic vein into the superior mesenteric vein. Lymph nodes follow the blood supply, draining into the superior mesenteric nodes (14).

1.4 Right iliac fossa pain: common conditions

1.4.1 Appendicitis

Appendicitis is defined as transmural inflammation of the appendix on histological examination (17). It is secondary to obstruction of the appendiceal lumen in 85% of cases and the two commonest mechanisms for this are proliferation of lymphoid tissue and the presence of a faecolith (9). The lifetime risk of having appendicitis is 7%-8%, with an overall incidence of 11

cases per 10,000/population per year (9,18,19). Peak incidence is in the second and third decades of life (18)(20). The incidence of appendicitis is higher in males than females with a ratio of 1.4:1 (18). There is geographic variation, with appendicitis relatively more common in industrialised nations and this is thought to be associated with the typical low-fibre diet of these counties (21). There is huge intra- and inter-hospital variability in the investigation and management of these patients (22). Correct and timely diagnosis is crucial to prevent complications (19). Various strategies have been used to assist clinical diagnosis including bloods, scoring systems and imaging.

1.4.2 Non-specific abdominal pain

Non-specific abdominal pain (NSAP) is defined as acute abdominal pain of less than seven days duration, where no diagnosis is reached after examination and baseline investigations (8) and therefore considered non-organic (23); it represents 13-40% of all surgical admissions with abdominal pain (11).

The use of early diagnostic laparoscopy in patients with suspected NSAP is debated. A 1999 randomized control trial (24) allocated participants into two groups: diagnostic laparoscopy within 18 hours of admission versus a 'watch and wait' policy. They showed a higher diagnostic accuracy and quality of life in the early intervention group. Others also favour laparoscopy in either diagnostic uncertainty (25) or chronic RIF pain (26–28). A 2008 review (29) concluded that although there was insufficient evidence to recommend routine use of early laparoscopy in acute abdominal pain, that there was also no evidence of harm. However others warn about the risks associated with potentially unnecessary laparoscopy (30) and the likelihood that up to 40% of patients diagnosed with NSAP do fit the Rome III criteria for irritable bowel syndrome (IBS) and do not benefit from a laparoscopy (23). Ten percent of patients presenting with NSAP, in the over 50 years age group have an intra-abdominal malignancy (31) and therefore CT scanning is advised (8).

1.4.3 Gynaecological pathology

Ovarian cyst rupture, tubo-ovarian abscess, ovarian torsion, pelvic inflammatory disease and ectopic pregnancy all commonly present with RIF pain. Urinary pregnancy test is mandatory for all referrals. Pelvic swabs should be conducted for any patient with vaginal discharge. A pelvic ultrasound (transabdominal and transvaginal) should be undertaken. Ovarian cyst rupture is often not accompanied by a rise in inflammatory markers.

1.4.4 Other pathologies

Diverticulitis, terminal ileitis, biliary pathology, renal colic, urinary tract infection and gastroenteritis are commonly seen as definitive diagnoses from patients referred with RIF pain (12). A urine dip should be performed on all patients. Diarrhoea is uncommon in appendicitis (16) unless there is a pelvic abscess so a stool sample for microscopy, culture and sensitivities should be sent for all patients with loose stools. The other pathologies listed above are diagnosed on imaging.

1.4.5 Investigation of right iliac fossa pain

Investigation of right iliac fossa pain in the acute surgical setting is performed in a variable manner across institutions but almost always involves history and examination, the use of biomarkers and imaging. In some institutions scoring systems are used. To form a basis for this research and to inform the clinical decision support tool a scoping review was performed. This methodology allows a broader interrogation then a systematic review and the aim is to establish the breadth of the existing literature with regards the investigation of right iliac fossa pain and to allow creation of the CDST with current best practice.

1.4.5.1 History and examination

A standard format for history taking is appropriate and necessary in the patient with RIF pain (9,32). A typical history for appendicitis is described as initial central abdominal pain with migration to the right iliac fossa. Patients often present with a one to three-day history and the pain may be accompanied by gastrointestinal (GI) upset and loss of appetite (16). However this may only be present in less than 50% of patients (19). Tenderness with or without peritonism over McBurney's point is classical for examination findings. Many authors have looked at features to distinguish between different pathologies (9,19,33). A typical history of ovarian or tubular pathology involves a sudden onset of low pelvic pain (which is non-migratory (32)) without GI upset and no loss of appetite (33).

1.4.5.2 Biomarkers

1.4.5.2.1 Literature search for biomarkers

A literature search was conducted with the search terms biomarkers or inflammatory markers with right iliac fossa pain or appendicitis. The results can be seen in the PRISMA diagram below in Figure 2.

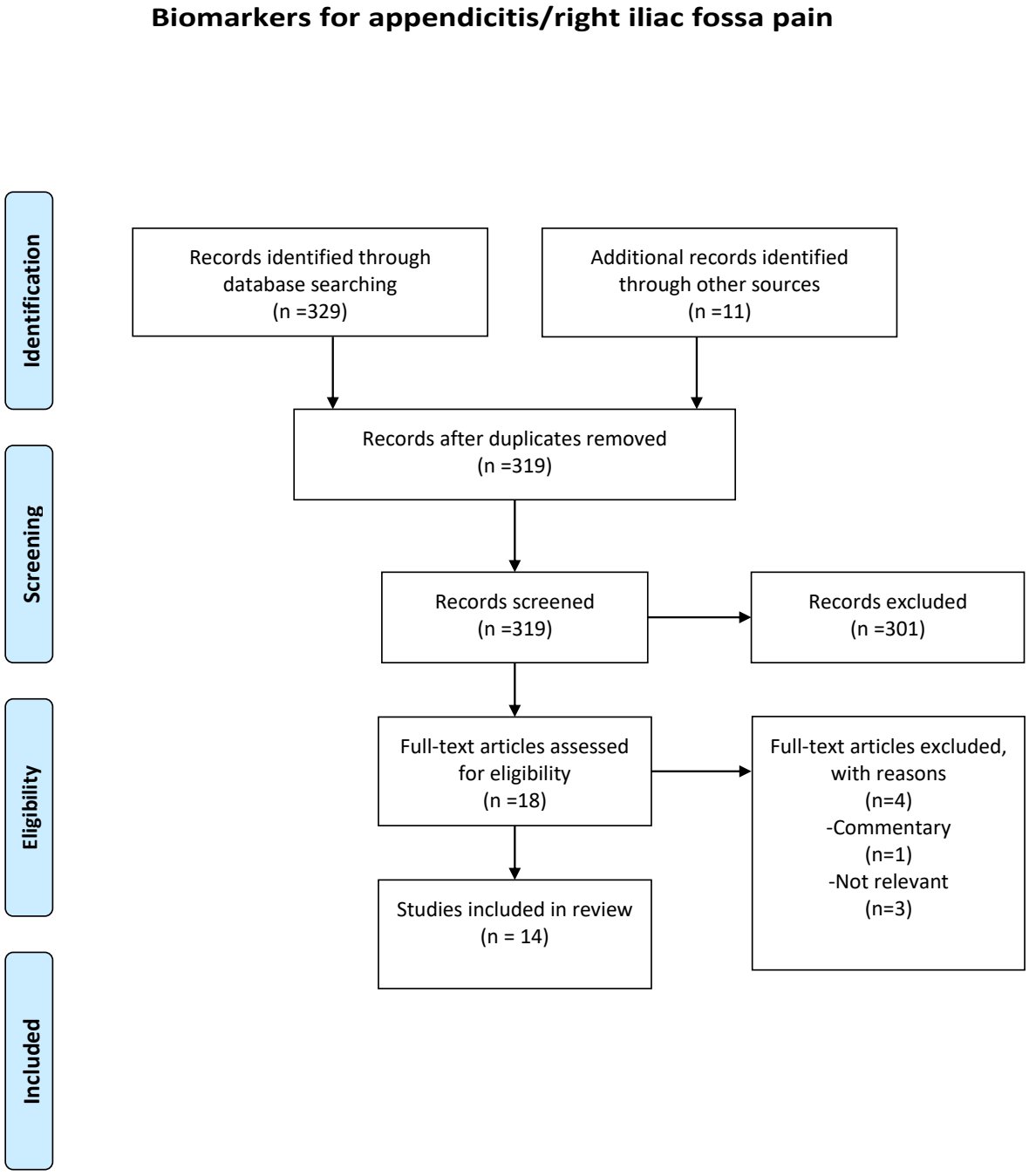


Figure 2 PRISMA diagram for literature search on biomarkers in right iliac fossa pain/appendicitis

In the context of patients presenting with RIF pain, a normal white cell count (WCC) and C-reactive protein (CRP) gives an extremely low likelihood of the patient having an acute appendicitis (34,35). A rise in both inflammatory markers gives a sensitivity of over 95% for the diagnosis (19,34,36). The positive predictive value is increased by having both a raised WCC and CRP (37,38). If the duration of symptoms is less than 12 hours then a rise in CRP may not be seen compared to WCC which will show an early rise and then fall (19,34). CRP is an independent marker, useful in diagnosis of appendicitis from other causes of RIF pain however using it in combination with leucocyte count increases the specificity. This is well supported in the literature

(19,36–41). A recent systematic review (42) showed while no blood markers have full accuracy, CRP does have the highest in the diagnosis of acute appendicitis.

Many other biomarkers have been looked at, but none are in routine use. They include: IL-1 to IL-10 (43) , bilirubin (44), procalcitonin (42), calprotectin (45), pancreatic stone protein (46), d-lactate (47), D-dimer (48), serum amyloid A (49), mean platelet volume (50), phospholipase A2 (51), leucocyte elastase (52), lactoferrin (45), plasma total-oxidant capacity (53), adenosine deaminase (54), lipopolysaccharide binding protein (55), and nuclear factor-kappaB (56).

More evidence may be available on this topic once the following Cochrane review is published: Biomarkers for diagnosis of acute appendicitis in adults (57).

1.4.5.3 Imaging

1.4.5.3.1 Literature search for imaging

A literature search was conducted with the search terms imaging (+/-CT +/- USS +/- MRI) with right iliac fossa pain or appendicitis. The results can be seen in the PRISMA diagram below in Figure 3.

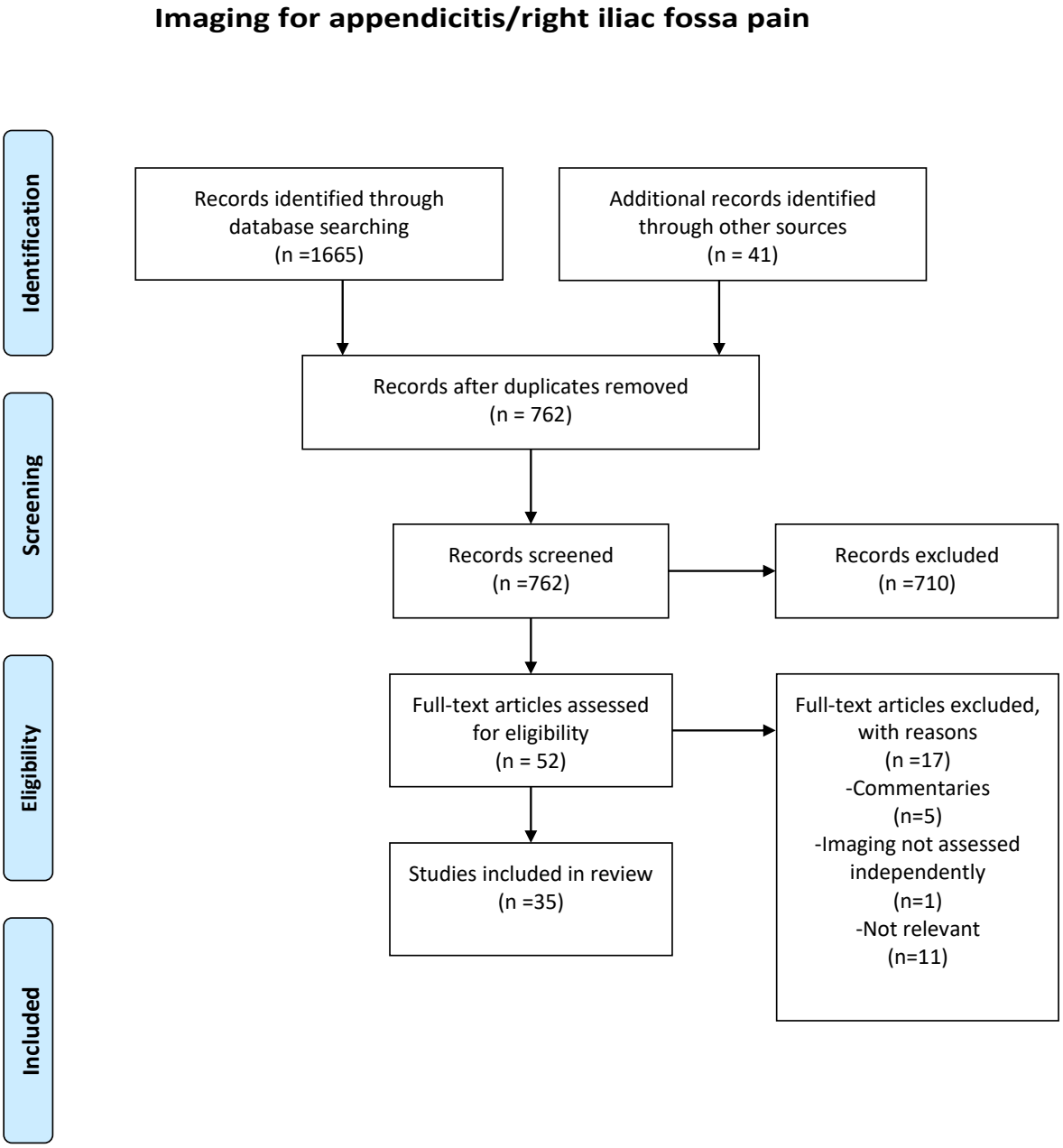


Figure 3 PRISMA diagram for literature search on imaging in right iliac fossa pain and appendicitis

Modern imaging techniques mean that imaging is more accurate and easily accessible. Its routine use has been widely adopted as an adjunct to clinical diagnosis in the assessment of RIF pain (58).

There is extensive research into the sensitivity and specificity of different modalities and the effect on preoperative diagnosis and subsequent management. However, there is no consensus or overarching guidance regarding the use and choice of imaging which means there is a wide variation in practice. Ultrasound (USS) and Computerised tomography (CT) scanning are most commonly used but Magnetic resonance (MR) imaging use is increasing in frequency (59–61). No imaging modality is perfect with each having their own flaws; there is large inter-user variability of ultrasound and variable quality of imaging equipment available in different centres and different countries; there are radiation and contrast considerations with CT scans; the limited availability

and time constraints of MR limits its use in a high-volume patient cohort such as RIF pain (62). The best available guidance is via the Government of Western Australia who have undertaken significant work to publish imaging pathways which are NICE (National Institute of Clinical Excellence) approved (63) as seen in Figure 4.

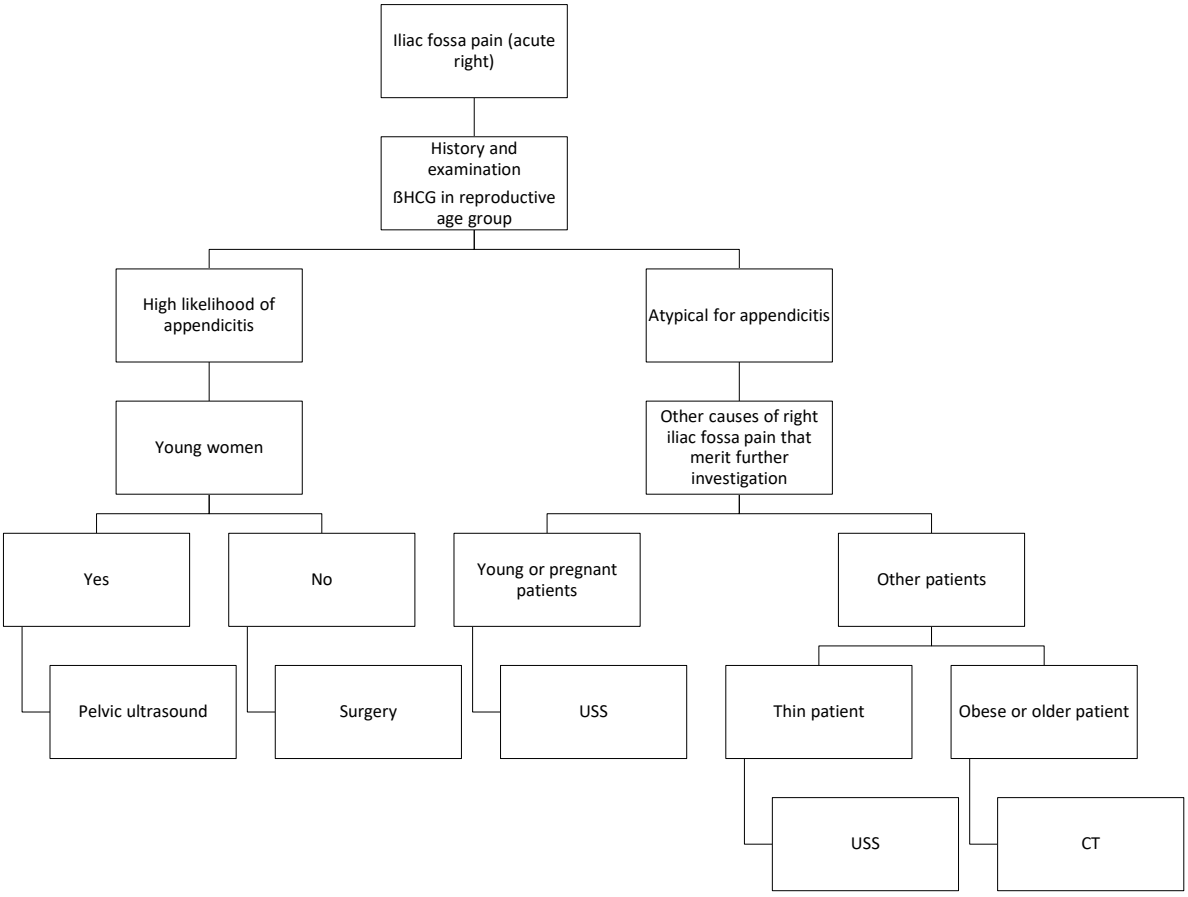


Figure 4 Diagnostic Imaging Pathways - Iliac Fossa Pain (Acute Right) - Government of Western Australia (63)

1.4.5.3.2 Ultrasound

The sonographic definition for appendicitis is 'an incompressible, blind-ended, fluid-filled, tubular structure with hyperaemic walls with a thickness of greater than 6mm' (14). Other secondary characteristics can also be used to indicate a diagnosis of appendicitis on USS, including: the presence of a faecolith, hyperechoic peri appendicular fat, peritoneal fluid or a collection (64).

The sensitivity of USS for a diagnosis of appendicitis is 59-83% and specificity is 86-97% (64–69). See Table 1. Advances in technology including graded compression have improved the accuracy of scanning (70). Graded compression involves applying steady pressure to the RIF with the

ultrasound probe with the aim of compressing the small bowel by emptying it of gas and thereby being able to identify the non-compressible inflamed appendix (71). In females a combined approach of transvaginal and transabdominal scanning improves accuracy (72), and this is routine practice in many units.

USS is non-invasive, quick to perform, cost effective and relatively mobile (73,74). This, along with its lack of ionising radiation makes it the first line imaging modality in younger patients.

1.4.5.3.3 Computerised Tomography

CT criteria for appendicitis and associated features are increased appendiceal calibre >6mm, increased appendiceal wall thickness, abnormal appendiceal wall enhancement, the presence of peri appendiceal fat stranding and fluid, intraluminal air in the appendix, thinning of the appendiceal wall, caecal wall thickening, appendicolith and perityphlitic abscess (75,76).

CT has a higher sensitivity and specificity for appendicitis than USS with a sensitivity of 88-100%, and specificity of 89-100% (64–69). See Table 1.

Table 1 Sensitivity and specificity of USS and CT for appendicitis

Paper	Number of patients	CT sensitivity	CT specificity	USS sensitivity	USS specificity
Balthazar 1994	100	96%	89%	76%	91%
Doria 2006	4341	94%	94%	83%	93%
Horton 2000	89	97%	100%	76%	90%
Poortman 2009	151	100%	100%	77%	86%
Styrud 2000	239	88%	95%	82%	97%
Unlu 2009	320	100%	95%	59%	91%

The cost benefits of CT scanning in RIF pain have been shown in a US population (77). The concern over ionising radiation in CTs is a significant factor in their use. A recent systematic review and meta-analysis has shown reduced dose CT to have a comparable diagnostic performance to standard dose CT. The reduced dose CT had a sensitivity of 96% and sensitivity of 94% showing no significant difference (78) from standard dose CT.

1.4.5.3.4 Magnetic Resonance Imaging

MR imaging features of appendicitis are a thickened appendix (diameter >7mm), peri appendiceal fat infiltration and restricted diffusion of the appendiceal wall (59). Sensitivity and specificity of MR imaging for appendicitis is 90-97% and 81-97% (79–81). Limited availability and high costs have previously reduced the use of MR in the acute setting for the investigation of RIF pain. In

larger units in the USA it is now being used more widely but is still not feasible in the majority of units worldwide (62).

1.4.5.3.5 Which patients should have imaging?

Patients with an equivocal diagnosis after initial assessment require imaging (64,82–86). Patients who, based on history, examination and bloods, have either a high likelihood or low likelihood of appendicitis do not require imaging. Those with a high likelihood should have a laparoscopy and those with a low likelihood, be clinically monitored (either in hospital or on an ambulatory pathway). The middle equivocal group should have either an USS or CT and some may require both. Both USS and CT are useful. USS should be favoured in women of child bearing age due to the high preponderance of gynaecological pathology. CT should be reserved for generally older patients where there may be colonic pathology as an alternative cause of their symptoms (83,87–89). There are three ongoing Cochrane reviews which are yet to report, one each, looking at USS, CT and MRI (90–92), which will add further evidence.

In 2009 Poortman et al (69) looked at the role of imaging within a diagnostic pathway. Their recommendations were that a pathway should involve the standard use of USS and an additional CT only in those patients with negative or inconclusive USS results. This method yielded a high diagnostic accuracy. They also noted that in patients with negative US and CT findings, a watch and wait policy was safe.

1.4.5.4 Scoring systems

Scoring systems for appendicitis have been developed with a view to 'ruling in' and 'ruling out' appendicitis. The most widely known of these is the Alvarado score but recent attention has been on the newly developed Appendicitis Inflammatory Response (AIR) score. I have focussed on these two scoring systems.

1.4.5.4.1 Literature search for scoring systems

A literature search was conducted using the terms score or scoring with right iliac fossa pain or appendicitis. The results are shown below in the PRISMA diagram seen in Figure 5.

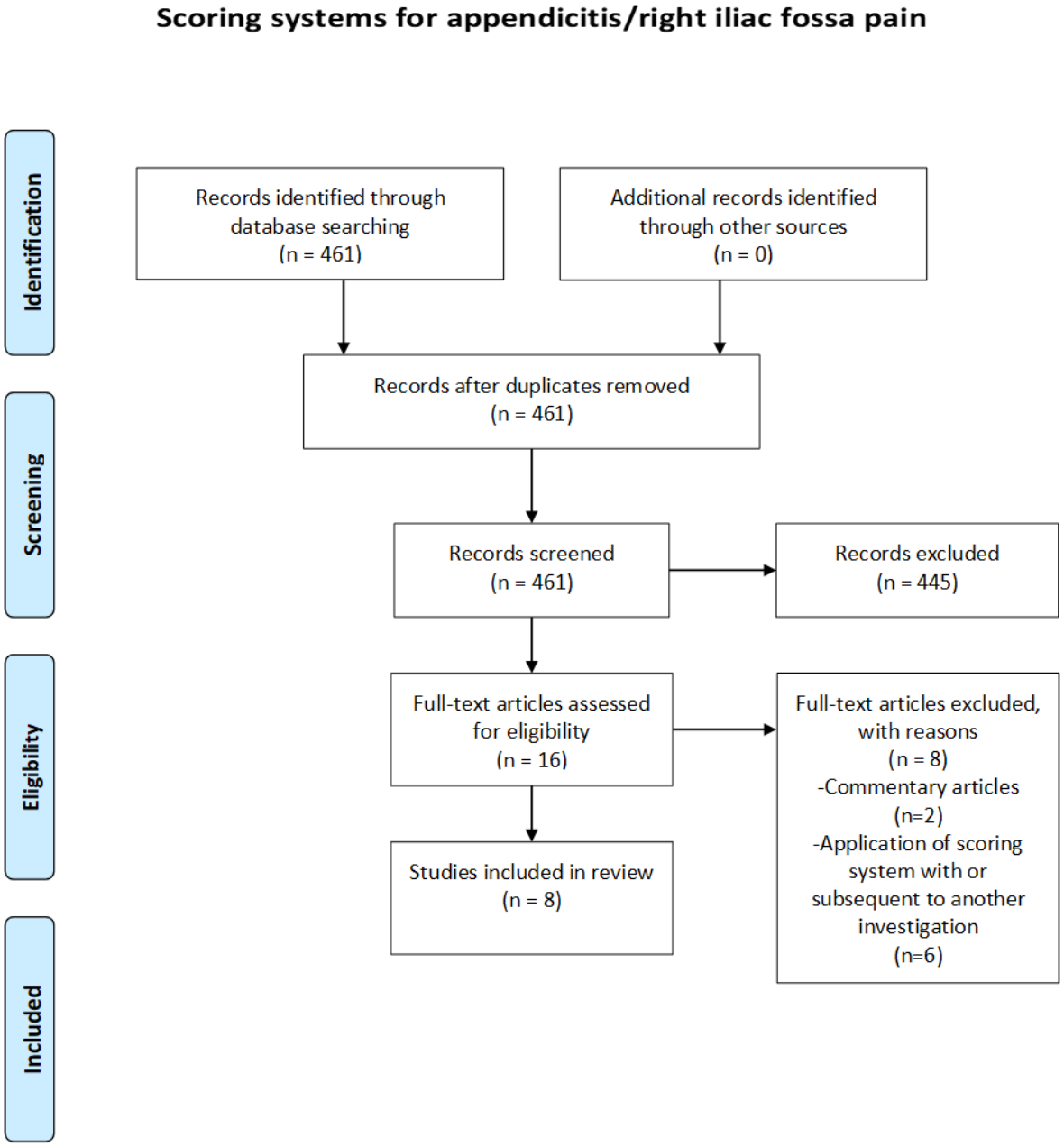


Figure 5 PRISMA diagram for literature search on scoring systems in right iliac fossa pain and appendicitis

1.4.5.4.2 The Alvarado Score

The Alvarado Score allocates points to the following signs, symptoms and laboratory tests giving a total possible score of 10 (see Table 2).

Table 2 Calculation of the Alvarado Score

		Value
Symptoms	Migration of pain	1
	Anorexia	1
	Nausea/vomiting	1

Signs	Right lower quadrant tenderness	2
	Rebound pain	1
	Elevation of temperature	1
	Leucocytosis	2
	Neutrophils >75%	1
Total score		10

Alvarado suggested a score of 5 or 6 was compatible with a diagnosis of appendicitis, a score of 7 or 8, a probable diagnosis of appendicitis and a score of 9 or 10, a very probable diagnosis of appendicitis.

Whilst the Alvarado score has been the most successful it does not have broad uptake among surgeons in day to day practice, due to various weaknesses (93). The Alvarado score performs poorly in women of child bearing age and in children (94).The score was written based on a retrospective review of patients who had been operated on for a possible diagnosis of appendicitis. This is not the same cohort of patients they are suggesting the score be applied to. This may lead to scoring weight bias (94). See Table 3 for the PPV and NPV for the Alvarado score from 3 large studies.

Table 3 Positive predictive values (PPV) and Negative predictive values (NPV) for the Alvarado Score

Paper	**Number of patients in study**	**PPV for appendicitis**	**NPV for appendicitis**
Andersson 2008 (93) Score ≥5 Score ≥9	545	 0.56 0.91	 0.98 0.73
De Castro 2012 (95) Score ≥5 Score ≥9	941	 0.53 0.77	 0.90 0.70
Tan 2013 (96) Score ≥5 Score ≥9	358	 0.62 1.0	 0.79 0.52

1.4.5.4.3 The Appendicitis Inflammatory Response (AIR) Score

Andersson et al have devised a new tool, the AIR Score (93), which in their Swedish population outperformed the Alvarado score and successfully selected the indeterminate group of patients which would benefit from further investigation and imaging. See Table 4 for the calculation of the score.

Table 4 Calculation of the AIR score

Sign/Symptom	**Value**
Vomiting	1
Pain in RIF	1
Rebound tenderness None Light Medium Strong	 0 1 2 3
Temperature ≥38.5	1
Proportion of neutrophils 70-84% ≥85%	 1 2
WCC 10.0-14.9 x10^9/L ≥15 x10^9/L	 1 2
CRP 10-49 g/L ≥50 g/L	 1 2
Total Score	12

Andersson grouped the patients into 3 categories; a score of <5 indicates a low probability of appendicitis, a score of 5-8, an indeterminate chance and a score >8, a high probability of appendicitis.

This score was validated by the Dutch group of de Castro (95) in their population, who found that it had a high discriminating power and again outperformed the Alvarado score. This scoring system has now been tested in a UK population. Scott (97) looked at validating this score and explored its potential as a risk stratification tool. They concluded that while their data does provide some evidence for the usefulness of the AIR score in assisting with RIF pain decision making, a randomised control trial is needed in this field. See Table 5 for the PPV and NPV for the AIR score from 3 large studies.

Table 5 PPV and NPV for the AIR Score

Paper	Number of patients in study	PPV for appendicitis	NPV for appendicitis
Andersson 2008 (93)	545		
Score ≥5		0.64	0.97
Score ≥9		0.97	0.76
De Castro 2012 (95)	941		
Score ≥5		0.79	0.95
Score ≥9		1.00	0.66
Scott 2015 (97)	464		
Score ≥5		0.49	0.94
Score ≥9		0.97	0.76

With justified concerns about exposure to irradiating imaging (98) and a wide variation in negative appendicectomy rates, we should use all available methods to select out patients that warrant further investigation or definite intervention. If validated, a scoring system allows allocation into these three groups with accompanying management:

1. High likelihood of appendicitis – proceed to laparoscopy
2. Low likelihood of appendicitis – discharge with outpatient review at 24 hours
3. Indeterminate – imaging

1.5 The Acute Surgical Unit

Over the last 13 years, in response to a concern over outcomes in emergency general surgery (EGS), the dedicated Acute Surgical Unit has been developed (4). The first Acute Surgical Units worldwide were set up in two New South Wales hospitals in Australia. The Prince of Wales Hospital (99) at Randwick in 2005 and the Nepean Hospital (100) at Penrith in 2006 developed this new model of care, comprising a consultant led and delivered service in an independent unit, staffed 7 days a weeks with complete separation of emergency and elective surgery (100,101).

1.5.1 **Different models**

There is wide inter-hospital variability in the form this service or team takes. Despite numerous centres having set up acute surgical units, only a limited number have published details of their individual models. Descriptive publications of ASU details come from Australia (99,100,102–107), New Zealand (108–110) and the United Kingdom (111,112). The United States of America (113–119) and Canada (120–122) have published extensively but their models are very different as they

contain not only emergency general surgery but also orthopaedics, general trauma and critical care all together in one programme and unit.

There are very different models used in different centres. The model adopted by a unit must meet the needs and capabilities of each individual department for it to be successful and sustainable.

Differing models consist of the following variations:

1. Consultant cover
    a. Nature of Consultant
        i. Dedicated ASU Consultants – main specialty
        ii. Elective Consultants who do a day or block of on-call
    b. On-call commitment
        i. 24 hours
        ii. 3- and 4-day split week
        iii. 1-week block
    c. Day/Night split consultant shift versus 24 hours consultant shift
2. Junior Team
    a. 3/4/6/12 month rotation – dedicated ASU team member
    b. Seconded from elective team for day/partial or full week
3. Physical environment
    a. ASU assessment area/ward
    b. No dedicated area – patients reviewed in the emergency department (ED)/seen on ward
4. Resources
    a. Hot clinic (new referrals/follow up)
    b. Dedicated radiology access
    c. Dedicated theatre
        i. Shared/not shared
        ii. Partial/full 24 hours

1.5.2 **Key elements**

In 2010 the General Surgeons of Australia association set out their 12 point plan for Emergency General Surgery, a consensus document aimed at improving emergency surgery provision in Australia(123). It outlines the key elements of any acute surgical model:

1. Emergency general surgery is a continuing core competency of a general surgeon
2. Emergency general surgery should be consultant led
3. There should be dedicated staff allocated to the provision of emergency care, with the need for training recognised
4. There should be separation of emergency general surgery and elective general surgery streams
5. There should be appropriate and timely access to emergency operating theatres

6. Emergency operations should be performed during the working day unless there is a threat to life, limb, or organ
7. Consultant surgeons should contribute to the efficient management of the emergency theatre
8. The period of service of the emergency general surgeon must be defined. Work practices must reflect safe hours principles
9. There must be robust handover and transfer of care: peer to peer, documented, and retrievable
10. Best practice should be defined. Quality should be measured by clinically meaningful Key Performance Indicators (KPI's)
11. The service must reflect community need and regional variation
12. The service must be valued (recognised, rewarded, resourced, and remunerated)

These values can be used to set up any Acute Surgical Unit. University Hospital Southampton set up its ASU in 2012.

1.5.3 ASU structure at University Hospital Southampton

The UHS setup is 6 Consultants, 2x Specialty Trainees (StRs), 3x Senior House Officers (SHOs), 3x Advanced Nurse Practitioners (ANPs), 4 Foundation Year 1s (FY1s) and a pathway co-ordinator. The staffing In-hours and Out-of-hours is as follows (see Table 6):

Table 6 UHS ASU Staffing levels

Weekdays	
Consultant (ASU)	8am – 8am (resident until 9pm)
StR 1	8am – 9pm
StR 2	8am – 5pm
SHOs/ANPs/F1s	Early and late shifts covering 7.30am to 9pm
StR/SHO/F1	Night shift 8.30pm – 8.30am
Weekend	
Consultant (GI)	Friday 12pm to Monday 12pm
StR/SHO/F1s – Day and Night	8am – 9pm/8.30pm – 8.30am

All patients referred to the Acute Surgical Unit are clerked using a proforma (see appendix). Patients are usually initially clerked by a junior clinician (F1, SHO, ANP) followed by a senior review (StR or Consultant).

1.5.4 Comparison with ASU models in Australia

During my research I spent 2 weeks at the Nepean Hospital and 1 week at the Prince of Wales Hospital in Sydney to observe ASUs in another country. These were 2 of the earliest ASUs in Australia and worldwide.

1.5.4.1 ASU Structure at Nepean Hospital, Penrith, Australia

Nepean Hospital is a 520 bedded teaching hospital in Penrith, NSW at the base of the Blue Mountains.

It has an ASU director whose primary commitment is to ASU. Consultants do 24 hours on call from 7pm to 7pm including single days over the weekend. There are 15 Consultants on the rota who do a day on call with varying frequency.

The junior team consists of:

1x Fellow (only ASU fellow programme in Australia) – daytime M-F

1x Accredited Registrar (early and lates (and 2nd on call nights if competent))

2x Unaccredited Registrars (early and lates, no nights)

1x permanent and 1x rotating/locum night registrar (CMO)

2nd on call overnight is provided by the senior ASU and other surgical departmental Registrars/Fellows (operating)

5x interns/residents (early and late shifts, not on surgical departmental OOH rota)

2x alternating Nurse Practitioners

The fellowship post is for a year and the registrars are on 6-month terms. The interns/residents are on 10-week terms. The Nurse practitioners are permanent appointments and have been with the unit since its inception.

Patient flow: All patients are assessed in ED and come from 3 main sources: self-presenters to ED, GP referrals and referrals from other hospitals. Consults from patients admitted under other specialties are also reviewed on the ward. There is no physical acute surgical assessment area or

ward. Most patients admitted under the ASU team go to either a short stay ward or the longer stay main general surgical ward.

Resources: There is a dedicated theatre list which is not shared by any other specialty. The list starts at 10am to allow the handover and morning ward round to be completed. This works extremely well and allows excellent planning and therefore utilization of theatre. There is easy access to CT and there is one reserved USS slot every morning for RUQ pain. ASU follow ups are allocated into the general surgical clinics of the on-call Consultant, but the ASU director attends the clinic and sees some of the ASU patients. All patients are tracked on discharge via a comprehensive database by the Nurse Practitioners. This ensures that pathology results and any additional outpatient investigations or referrals are not overlooked.

In general patients stay under the ASU team. Patients with a clear need to be treated under the subspecialty teams are transferred to those services although this happens rarely. Complex patients who require a higher level of continuity of decision making are placed under the ASU director but still looked after by the ASU junior team. There is an interesting interface between public and private that is not seen in quite the same way in the UK. A higher percentage of the population overall in Australia has private insurance. Private patients who get admitted as an emergency stay under the ASU but get their operation done by a Consultant and then should be taken over by that Consultant and their elective team.

Each day starts at 7am with a formal list handover of all the patients with review of bloods and imaging. This is followed by a Consultant led ward round and then theatre at 10am. The on-call pager is held by one of the registrars and they see referrals in ED. The four-hour wait is closely enforced as in the UK and ASU is required to see patients in ED within one hour maximum. Patients often wait a long time in ED for a bed. There is a large area in ED which is chair based where patients cannot receive IV fluids.

1.5.4.2 ASU structure at Prince of Wales Hospital Randwick, Sydney, Australia

The Prince of Wales is a 440 bedded hospital in Randwick, Eastern Suburbs, Sydney. Consultants from the general surgical department rotate through 2.5 days of ASU from Monday 7am to Wednesday 12pm to Friday 6pm. The night registrar hands over to the day team at 7am each morning and the Consultant ward round is usually about 8am. Admission numbers vary but usually average 6-8 patients/24 hours. At the end of each 2.5 day rotation any undifferentiated patients are kept by the ASU team and handed over to the incoming Consultant but the majority are kept by the departing Consultant and his home team.

The junior team consists of

1x accredited Registrar (days 7am-5pm)

1x unaccredited Registrar (nights 10pm-7am – as part of relief term)

1x SRMO (days 7am-5pm) – on OOH ward cover rota

1x clinical nurse consultant (5 days/week)

5pm to 10pm cover is provided by rota of registrars in the surgical department including the ASU registrar.

Patient flow: All patients are assessed in ED (or consults requested from other teams on the ward). The ED 4-hour rule applies. There are minimal referrals from other hospitals. Patients then go straight to a surgical ward.

Resources: There is a Hot clinic which is essentially an ED review clinic. It is staffed by the registrars and is flexible but can be daily. There is not a dedicated theatre, the emergency theatre is shared with paediatric, plastics and maxillofacial emergencies. It starts at 8am. Private patients sometimes get done in the private hospital if the Consultant on has an elective list there, but this seems to be relatively uncommon. There is a rather different model for post-operative care. Patients only likely to require a 1-night stay (abscess drainage, appendicectomy, cholecystectomy) stay in recovery overnight and are discharged from there. If they need an inpatient bed after that it is procured.

In both units the major frustrations were with the interface with the Emergency Department, similar to the UK.

1.6 Clinical decision tools

A clinical decision tool is “an active knowledge resource that uses patient data to generate case-specific advice, which supports clinical decision making” (124). It has both diagnostic and prognostic roles.

In 2006 the Health Technology Assessment NHS R&D HTA Programme carried out a systematic review of clinical decision tools for acute abdominal pain (125) focusing on acute appendicitis. They reviewed 32 studies, all based in secondary care comparing the diagnostic accuracies of doctors aided by decision tools with unaided doctors. They also looked at the impact on patient outcomes when a decision tool was used, the factors likely to determine the usability of the tool and the health economics involved. They determined that decision tools are potentially useful in confirming a diagnosis of acute appendicitis but not in ruling it out as they showed significantly

greater specificity and lower false-positive rates than unaided doctors. In one randomised trial (n=5193), doctors who were not allocated a decision tool had significantly higher admission rates (42.8%) than those who did use a tool (34.2-38.5%). Their cost-effectiveness comparison showed a paper checklist to be 100-900 times more cost-effective than a computer-based decision tool. They concluded that the use of a well-designed, condition specific decision tool could benefit patient outcomes and is worthy of further research. The most successful tools were developed by local clinicians and individualised to the local environment.

Liu et al (124) stated four defining characteristics for a successful clinical decision tool:

1. Target decision maker: the tool is designed to aid a clinical decision by a health professional and/or patient.
2. Target decision: the decisions concern an individual patient.
3. Knowledge component: the tool uses patient data and knowledge to generate an interpretation that aids clinical decision making.
4. Timing: the tool is used before the health professional takes the relevant decision.

The clinical decision support tool (CDST) in this study was designed according to these principles.

1.7 Aims of the study

The first part of this study was to look at the factors affecting the diagnostic pathway of patients presenting with RIF pain.

The second part of this study was concerned with the design of a clinical decision tool embedded within a specific RIF Pain clerking proforma.

The intervention element of this study evaluated the implementation of the clinical decision tool. The aim of the clinical decision tool was to improve the decision making of the junior clinician clerking the patient. When the junior clinician does not make an appropriate plan to initiate investigation and treatment, overall management of the patient can be delayed until a senior review has taken place. The variable on-call demands placed on the registrar or Consultant can mean a significant delay before a senior review occurs. Common examples of this are related to imaging not being requested, patients remaining nil by mouth unnecessarily or patients not being discharged onto an ambulatory pathway.

The primary endpoint of this study was the proportion of senior review plans that agreed with the junior clinician initial plan, indicating that the plan of the junior clinician was appropriate.

Secondary endpoints were time taken from ASU admission to the definitive diagnosis; time to theatre; and total length of stay.

Chapter 2 Methods

This chapter describes the process for gaining ethics, general techniques and specific investigative and analytical methodologies used to achieve the aims of this research.

2.1 Research Governance

The principles of the Department of Health research governance framework (RGF) for health and social care (2001, revised 2005) need to be met by the study as well as the local research and development (R&D) general policy.

2.1.1 Ethics

This sets out key principles to ensure integrity and quality, informed consent of participants, confidentiality, voluntary participation, avoidance of harm to participants and avoidance of conflicts of interest in the research. It outlines the legal and moral responsibility of a researcher so that patients enrolled in a study are protected by the principles of good clinical practice (GCP).

2.1.1.1 Ethical committee approval

The study was submitted to the University of Southampton online Ethics and Research Governance System (ERGO) and approved on 28/08/2014 (Ethics ID:9861). It was deemed a Service Improvement project and therefore not required to be put through the national Integrated Research Application System (IRAS).

2.1.1.2 Ethical considerations

The main ethical considerations for this project involved the storage of confidential patient information and data.

2.1.2 Consent

No patient consent was required for this study.

2.1.3 Pseudoanonymisation

To ensure confidentiality to the patients whilst not losing the benefits that come from a prospectively maintained database, the local research and ethics committee required the database to be pseudoanonymised and maintained on an encrypted server.

2.2 Identification of patients

All patients referred to the Acute Surgical Unit with RIF pain were potentially included in this research. Exclusion criteria were patients aged younger than 16 years (the Paediatric Surgery service sees these patients) and patients with a previous appendicectomy.

The referral pathways were via General Practitioners, the Emergency Department, intra-hospital referrals from other specialties or directly from Cruise ship doctors.

Applicable patients were identified via the electronic software programme 'Doctor's Worklist' admissions mode list for each day during the study and cross-referenced with the Acute Surgical Unit daily admissions list. The 'Doctor's Worklist' is an in-house (University Hospital Southampton) developed software programme with an admissions mode list that is maintained by the on-call surgical team. It contains details (including presenting complaint or referral diagnosis) for every patient seen by the surgical take. This list was monitored daily for any patient referred with RIF pain. When the listed diagnosis was vague such as 'abdominal pain' the notes, the emergency department documentation or GP referral letter were reviewed to select those patients appropriate for inclusion in the study. The Acute Surgical Unit also maintains a hand-written paper list of all Emergency department and GP admissions This was cross-referenced to the Doctor's Worklist and no discrepancies were found.

2.3 Investigations

WCC and CRP normal ranges are based on University Hospital Southampton laboratory normal values: WCC 4.0-11.0 x 10^9/L; CRP 0-7.5 mg/dL.

Ultrasound scans were performed by Sonographers, Radiology Consultants and Specialist Registrars. The ultrasound scanners in use were GE Logiq S8 and E9. The CT scanners in use were Siemens sensation 64 and GE Discovery 750 HD.

2.4 Data collection

The study contained three phases of data collection.

2.4.1 **First phase: Initial data collection**

The first phase aimed to inform the parameters of the study and informed the refinement of the research question. The initial data collection ran over a five-week period in January-February 2014.

2.4.2 Second phase: Pilot study

The second phase was a pilot study and was conducted over two time periods: April-June 2014 and August-September 2014 using a prototype decision tool and proforma.

2.4.3 Third phase: Implementation

The third phase involved full use of the completed proforma with CDST from January to June 2015.

All data was collected on a specifically designed case report form (CRF) and then entered into a Microsoft Excel® database by the author. Data was sought from the patients' paper and electronic medical records, including the electronic programmes eDocs, eQuest, JAC e-prescribing, PACS (picture archiving and communication system) and HICCS (theatre operation note software). eDocs and eQuest are software programmes that have been developed in house at University Hospital Southampton.

The number of data points on the CRF for the initial data set was 44, this was increased to 51 for the pilot and 53 for the implementation data set.

All patients had 90 days follow-up post discharge, including further contact or re-presentation to UHS.

2.5 Data analysis and statistics

Data analysis was conducted in Microsoft Excel® 2016 and statistical analysis in GraphPad Prism® 7.04. Continuous variables are described as means when normally distributed or median when non-normally distributed. Comparison of continuous variables was by unpaired t-tests or Mann-Whitney U tests, as appropriate. Categorical data are reported as absolute values and percentages where appropriate, and differences were analysed by χ^2 and Fisher exact tests. Statistical uncertainty was estimated using 95% confidence intervals and significance was attributed at the 5% level.

2.6 Development of the clinical decision support tool

The CDST consisted of two parts: an educational guide to common differential diagnoses of RIF pain and a management algorithm to aid clinical decision making.

2.6.1 Literature search

The review of the literature informing the initial design of the CDST was conducted as a scoping review using the methodology described by Arksey and O'Malley from the University of York(126). There are five key phases to the process as shown in Figure 6.

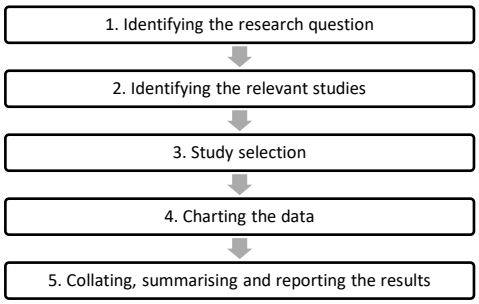


Figure 6 Phases of scoping review

2.6.1.1 Identifying the research question

The research questions for this review were:

- What biomarkers are the most commonly used to assist diagnosis in right iliac fossa pain? Which are the most useful?
- What imaging is most commonly in use to assist diagnosis in right iliac fossa pain? When should different image modalities be used?
- How useful are the Alvarado and AIR scoring systems in the diagnosis of right iliac fossa pain?

3 separate searches were carried out on these topics.

2.6.1.2 Identifying the relevant studies

A wide range of electronic databases were searched to ensure a comprehensive mapping of the research field. PubMed (from 1946), Embase (from 1949), Cochrane library and Google Scholar to December 2017 were searched using the search terms listed in each section in the introduction. English and American variations of spellings were used. Only full original articles written in English were included. There was a focus on published and peer reviewed literature. The references of selected studies were also checked using the same limits as the initial review.

2.6.1.3 Study selection

Studies were included when they reported findings relevant to any of the above research questions. Studies were excluded if they did not show separate data for the different factors

affecting the diagnostic process, when they were found not to be relevant to the research questions or when they were commentary articles as opposed to original data.

2.6.1.4 Charting the data

Data synthesis and interpretation adopted a narrative approach as described by Armstrong et al(127), seen in each relevant section of the introduction.

2.6.1.5 Collating, summarising and reporting the results

Descriptive statistics were used to present the data, seen in each section of the introduction.

2.6.2 Initial data collection

The analysis of the initial data contributed to the first version of the proforma and CDST used in the pilot study.

2.6.3 Pilot study

Conducting the pilot study resulted in various changes to the CRF, the exact data points collected and the layout and content of the clerking proforma and the integrated CDST.

It was clear from collecting the data and using the CRF in the pilot study that a small amount of further data needed to be collected to fully answer the research questions proposed at the outset.

The logistics of running the pilot study, the use of the CRF and feedback from clinicians all contributed to making changes to the CDST and the proforma until the final version (version 7) was achieved.

The analysis of the pilot study data was presented locally within the department. This highlighted both the area of research interest to clinicians and was a chance to promote the use of the proforma in the upcoming implementation stage.

Despite every effort, as outlined below, universal use of the RIF pain clerking proforma was not achievable, and therefore it would be important to collect data on the differences in outcome between when the proforma and tool were and were not used.

2.7 Clinician survey

Two questionnaires were conducted using *iSurvey – Online questionnaire generation from the University of Southampton*. These were carried out pre-implementation to guide the design of the clinical decision tool and post-implementation to gain user feedback.

The pre-implementation questionnaire was designed to assess the familiarity of clinicians with clinical decision support tools, their thoughts on whether it would be of benefit and its appropriateness in the setting of RIF pain management. A combination of questions requiring structured and free text answers were used. The questionnaire was distributed via email to all Acute Surgical Consultants, General Surgical Registrars and Fellows, Core Surgical Trainees and Foundation doctors in a General Surgical post. Responses were stratified by grade of clinician. Results were used to guide ongoing development of the tool and the proforma.

The post-implementation questionnaire gauged use of the tool, whether clinicians had found it helpful and whether it had subjectively changed their practice. Again, structured and free text answer questions were used. The questionnaire was distributed via email to all trainees who had responsibility for clerking patients on the Acute Surgical Unit during the use of the CDST in the RIF pain proforma (January- June 2015). This included all clinicians on the Registrar and Senior House Officer level on-call rota and Foundation doctors doing an Acute Surgical Unit rotation. The questionnaire was distributed in August 2015 after the completion of the implementation period. Consenting clinicians were contacted to discuss their thoughts face-to-face. Results were used to stimulate thoughts on future development of the tool and proforma as outlined in the discussion.

2.8 Development of the clerking proforma

The Right Iliac Fossa pain clerking proforma improved on the standard Acute Surgical Unit clerking proforma in two ways. Firstly, it made the functional clerking aspect more efficient, personalised to RIF pain and focusing on relevant aspects of history and examination. In addition, it guided the clerking clinician to think about the type of RIF pain diagnosis (highly likely appendicitis, indeterminate, highly unlikely appendicitis or highly likely other diagnosis) and therefore the initiation of appropriate investigation and management. Secondly it incorporated the CDST and accompanying educational content.

The outline of the clerking proforma was based on the pre-existing acute surgical unit clerking proforma template. It was re-designed in Adobe InDesign® including style guide information and relevant logos supplied by the University Hospital Southampton Information Technology Department and was printed by the hospital.

2.9 Use of proforma incorporating clinical decision support tool

The proforma incorporating the CDST was launched with presentations to key stakeholders. Education and information about the new initiative and the accompanying research goals were explained to the nursing staff on the Acute Surgical Unit with support from the senior nursing leadership. Information posters were placed on the wall of the Unit to act as reminders to use the new proforma when the referring diagnosis was RIF pain. The printing of the initial batch of proformas was organised by the author and then subsequently by the ward clerk on the Unit.

Discussions were undertaken at the outset of the study period with the Emergency Department leadership team about the use of the proformas in their department. Despite initial enthusiasm it was subsequently felt it would take too much time and be too confusing to use a different set of documents to the standard Emergency Department paperwork.

The medical clinicians were introduced to the new proforma via a variety of methods. An email explaining the purpose and details of the research and the proforma went to all General Surgical Consultants and Registrars in the department. An education session on the common differentials of RIF pain and how they should be investigated including details of the new proforma was delivered at the departmental Foundation doctor and SHO inductions. All personnel were given an opportunity to ask questions and any concerns were addressed. During the study period, twice weekly emails to on-call clinicians of all grades were sent as reminders to use the proforma.

2.10 Definitions of data points

Time of arrival was taken from Acute Surgical Unit nursing admissions paperwork.

Examination findings and provisional diagnosis were as documented by the clerking clinician.

Imaging results were taken from verified Consultant Radiologist reports.

Alvarado and AIR scores were calculated by the author based on documented data. Any queries over examination findings were clarified with the clerking clinician. This methodology has previously been described.

Definitive diagnosis was defined in four ways in decreasing order of importance: as defined by histology; description of operative findings if no specimen was taken; on radiology; and by documented clinical decision by the most senior clinician at patient discharge.

The date and time attributed to the definitive diagnosis were as per the above events. The only additions to these were culture results for urine or stool infections which confirmed clinical diagnoses.

Operation dates, times and details were taken from data submitted by the surgeon into the electronic operation note.

Date of discharge was taken from the electronic discharge management system.

Details of readmissions or further attendances to ED/outpatient clinic or the Acute Surgical Unit up to a minimum of 90 days post discharge were generated from interrogation of the electronic medical record of each patient.

Length of stay was calculated in days. A patient attendance and clinical review without admission was noted as a length of stay of 0 days. Admission was defined as per the documented criteria of our unit.

Chapter 3 Preliminary work

3.1 Initial data collection

After establishing the need to research factors affecting the diagnostic pathway of patients presenting with RIF pain, an initial data collection and subsequent piloting of a prototype proforma including CDST was embarked upon.

The aims of the initial data collection were to establish current local practice, trial data collection methods, establish what data to collect, inform pathway design and get a baseline assessment of the number of patients in the inclusion cohort. As there were no reports in the literature of a specific RIF pain clinical decision tool then this was the trialling of a new intervention without an evidence base meaning a sample effect was not known and a power calculation was not possible. Mitigation of this situation was attempted by maximising recruitment and volume of numbers.

The initial data collection took place over two time periods. The inclusion and exclusion criteria were the same as stated in the methods for the overall study. All patients had a 30 day follow up checking for morbidity and readmission. The initial plan was for the data to be collected by 3 F1 doctors who were working in the Acute Surgical Unit and supervised by the author. On early review however at 5 weeks (55 patients), it became clear that the data collection was not robust enough (data points missing). The decision was made for the author to collect all data personally to ensure accuracy and consistency. This was reflected in the second period of initial data collection which lasted two months and included a further 148 patients.

Data collection points included demographics, time taken to set points along the diagnostic and management pathway, details of imaging undertaken, comparison of current scoring systems and details of operative management and definitive diagnosis of all patients. It was hypothesised that age, gender, BMI and referral source might have an influence on factors affecting the diagnostic pathway. BMI specifically was felt anecdotally to make both clinical and USS examination less reliable.

The baseline characteristics of the patients in this initial data confirmed that our unit's cohort is an accurate representation of patients that present nationally with RIF pain. The methods of patient identification, the CRF and data collection itself were all shown to be accurate and feasible.

3.2 Piloting of the proforma and CDST

The RIF specific clerking proforma and incorporated CDST were being developed during this time as documented in the Methods (2.6). A pilot study of this proforma and CDST was conducted for a 6-week period with 100 eligible patients identified and data collected. Only 17 patients had the new proformas used. The main outcome of the pilot study was an awareness of the difficulty in getting clinicians to remember to use the new proforma and CDST rather than defaulting to the existing proforma which was still in use for most other admissions to the Acute Surgical Unit (ASU). This prompted a plan for a launch of the study. This involved targeting each grade of doctor separately and explaining the tool within the proforma and its goal. There was engagement of the Acute Surgical Unit senior team and nursing staff. Information posters were put up in the ASU office informing clinicians about the study. Weekly emails were sent to the doctors on call each week as a reminder to use the new proforma where appropriate. Throughout all this information dissemination, contact details for queries were made widely available.

3.3 Changes to the proforma, CDST and CRF

Specific changes were made to the proforma and CDST after it was reviewed in face-to-face interviews with 6 clinicians and also the ASU lead Consultant – these are specified later in this chapter (3.4.8).

The initial data collection and pilot study prompted the following changes to the CRF,

Added:

- Use of proforma and grade of clinician using it (as it was clear from the pilot study that despite best intentions it was likely that there would not be 100% use of the new proforma)
- Whether guidance contained within the CDST was followed - this could be with or without the use of the proforma
    - The RIF proforma might not be used but the clinician, in their plan, did what the CDST would have suggested
    - Conversely the RIF proforma could be physically used but the guidance of the CDST not followed
- Calculation at the point of data collection of the Alvarado and AIR scores
- Documentation of the use of ambulatory care in the pathway
- Recording of the Clavien-Dindo score
- Readmission data

Removed:

- Documentation of antibiotic use – decided to be beyond the scope of this study

Documentation of urine dip – again beyond the scope of this study.

3.4 Pre-implementation survey

3.4.1 Aims

The aim of this survey was to obtain the current understanding and opinions concerning clinical decision support tools, of the clinicians who would be using it. The survey was split into three sections. The first covered basic demographics of the clinician including grade and their role on the Acute Surgical Unit. The second concerned their views on clinical decision support tools. The third was a free text box asking clinicians about what area they would like further information on. Clinicians who consented were approached for a follow up decision face to face to get their further opinions.

3.4.2 Methods

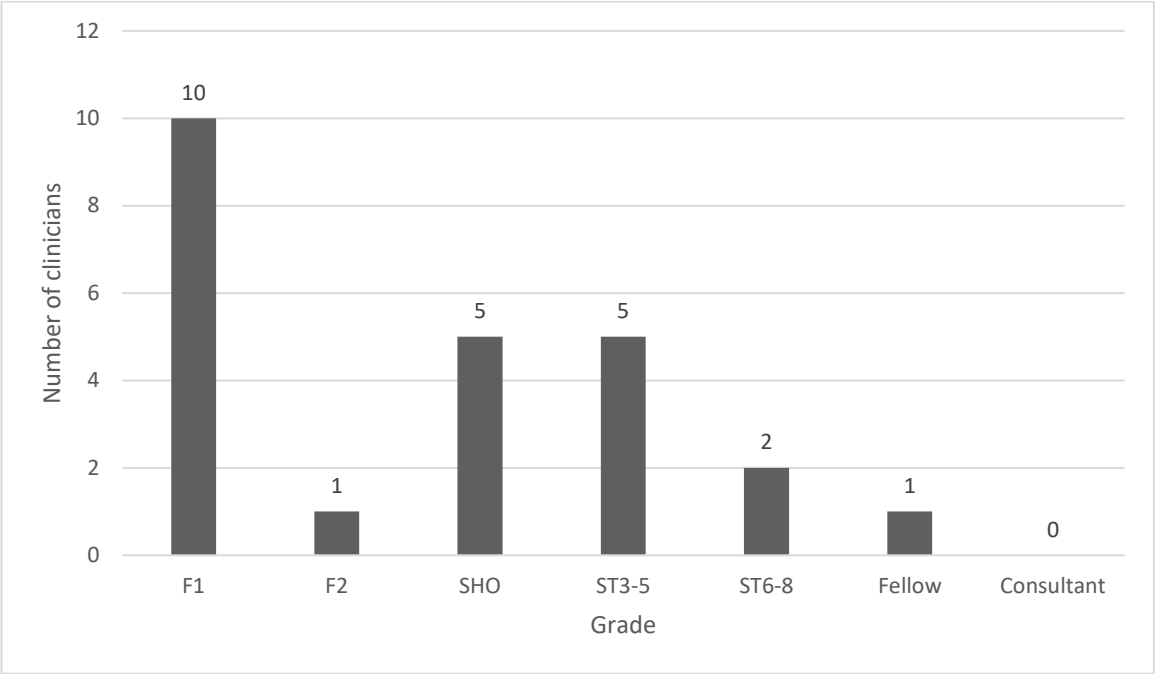
The survey was distributed via email to all Acute Surgical Consultants, General Surgical Registrars, Core Surgical Trainees, Trust fellows and Foundation doctors in a General Surgical post. 58 clinicians were sent the questionnaire. Reminders were sent 14 days after the initial email.

3.4.3 Results

Of the 58 clinicians approached, there were 26 responses to the survey (44.8% response rate). 24 respondents had complete data.

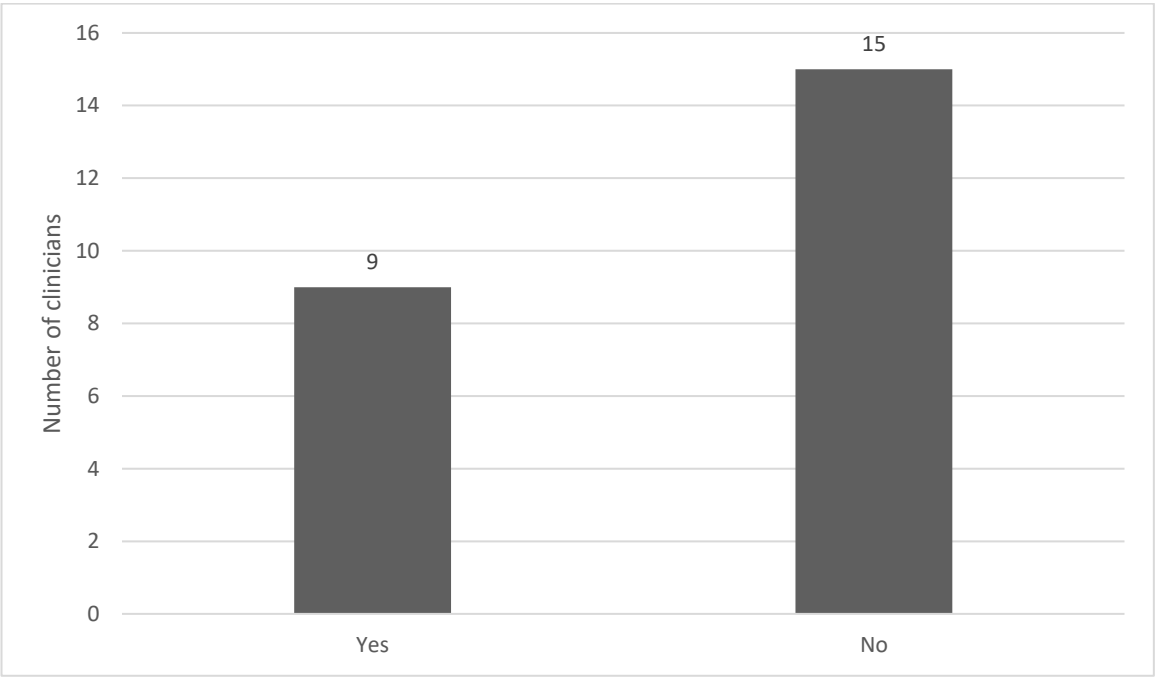
3.4.4 Structured questions

3.4.4.1 What grade are you?



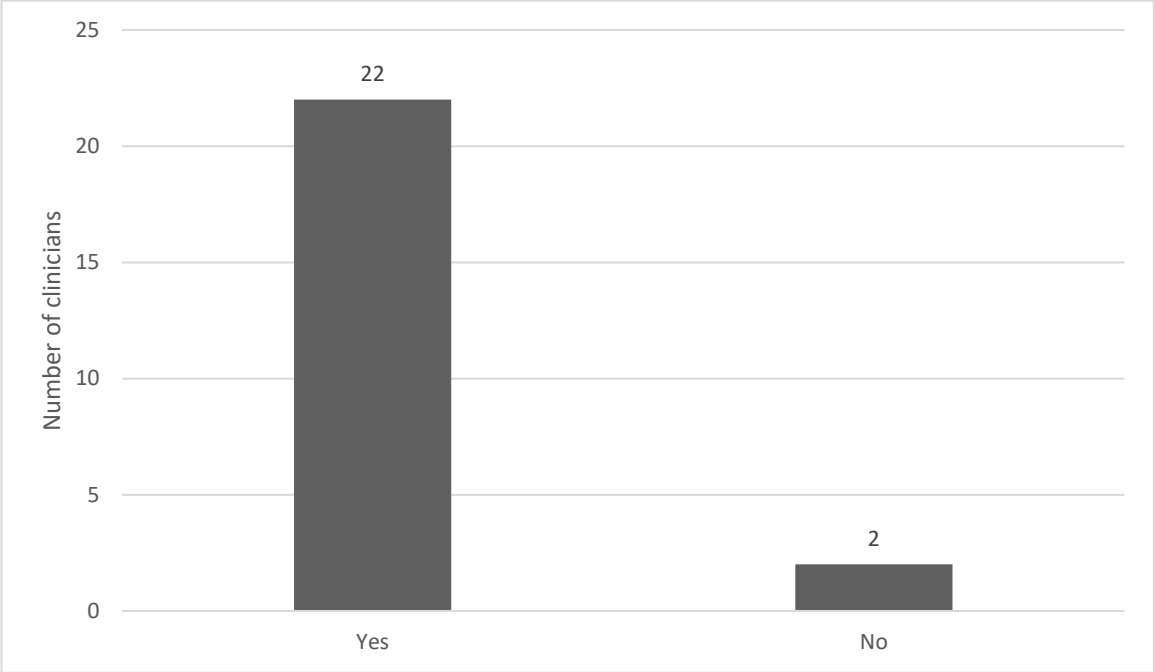
A range of doctors in different stages of their training completed the survey; 10 Foundation Year 1 doctors, 6 doctors on the 'SHO level' rota (Foundation Year 2 doctors, Core Trainee doctors years 1 and 2 and trust grade doctors) and 8 doctors on the middle grade rota.

3.4.4.2 Do you currently or have you previously worked as a 'day job' on the ASU team (excluding on call)?

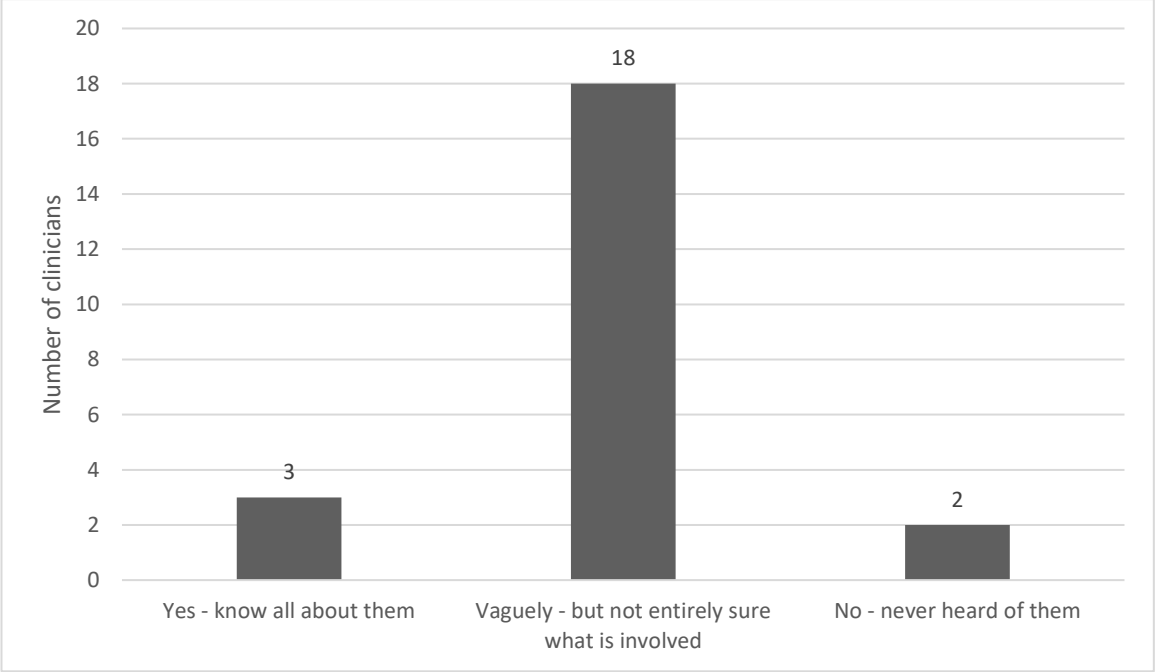


In the surgical department, the acute surgical unit is staffed by two cohorts of doctors. F1s and F2s doing 4-month rotations exclusively on the ASU and then StRs and SHOs doing on-call days, weekends and nights in groups of four and three days on a standard rolling rota.

3.4.4.3 Are you part of an on-call rota that covers the Acute Surgical Unit?

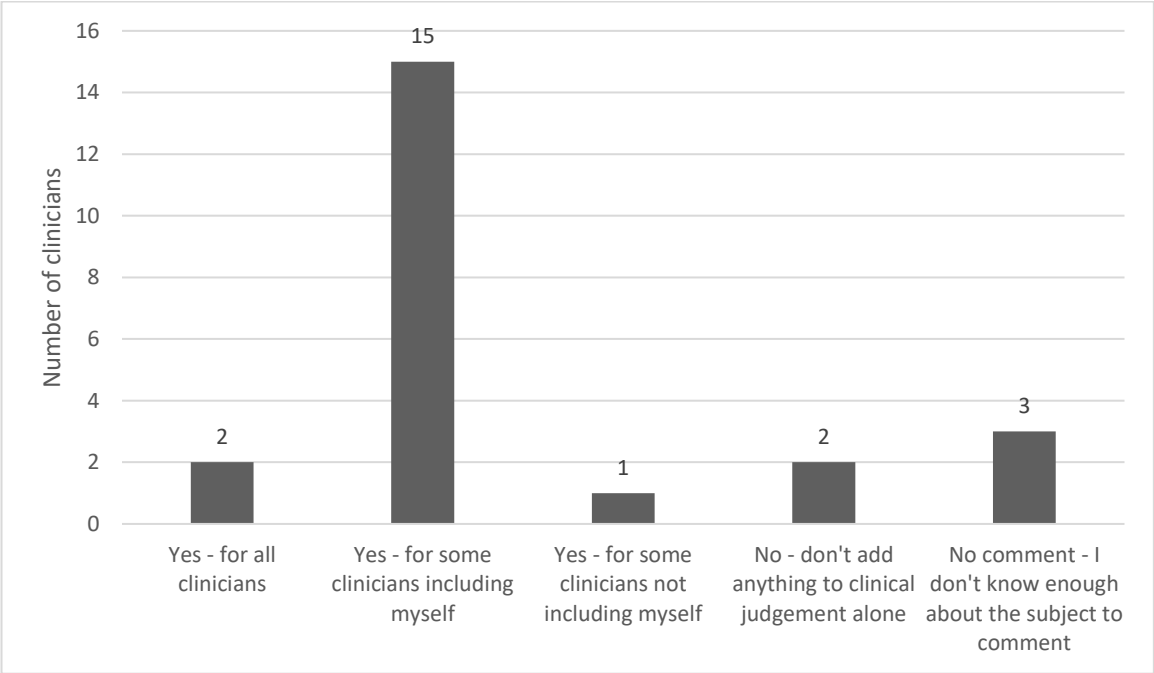


3.4.4.4 Have you heard of the phrase clinical decision aid or clinical decision support tool?



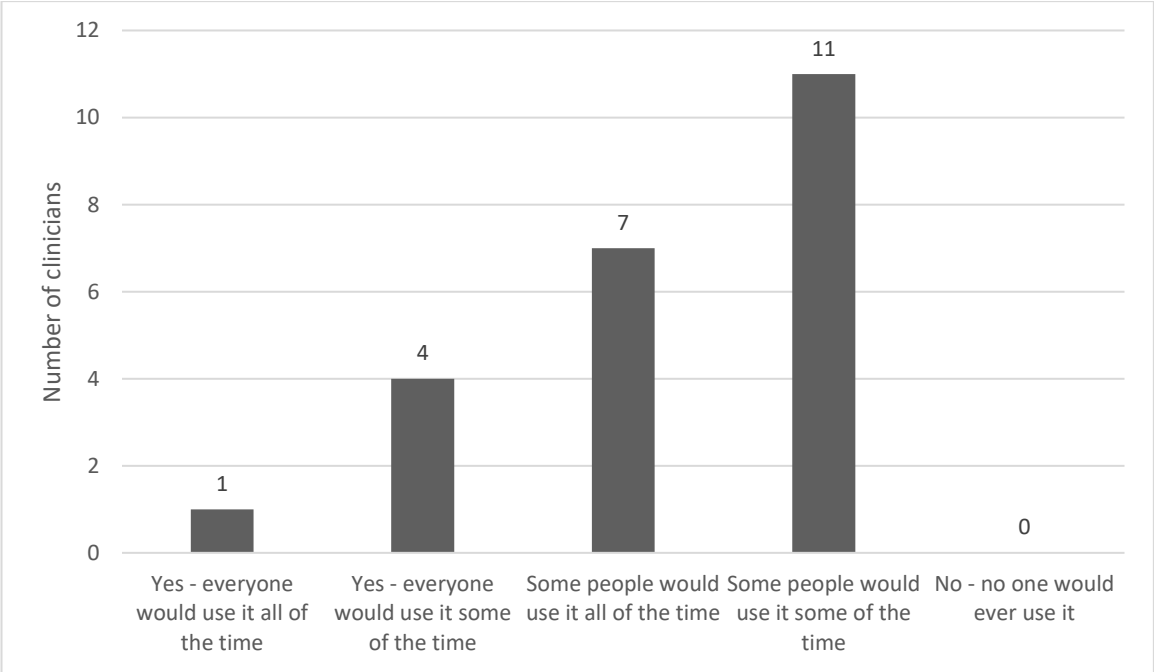
78.3% of respondents only had a vague idea of what CDST was.

3.4.4.5 Do you think a clinical decision support tool could be beneficial in the setting of the diagnosis of right iliac fossa pain?



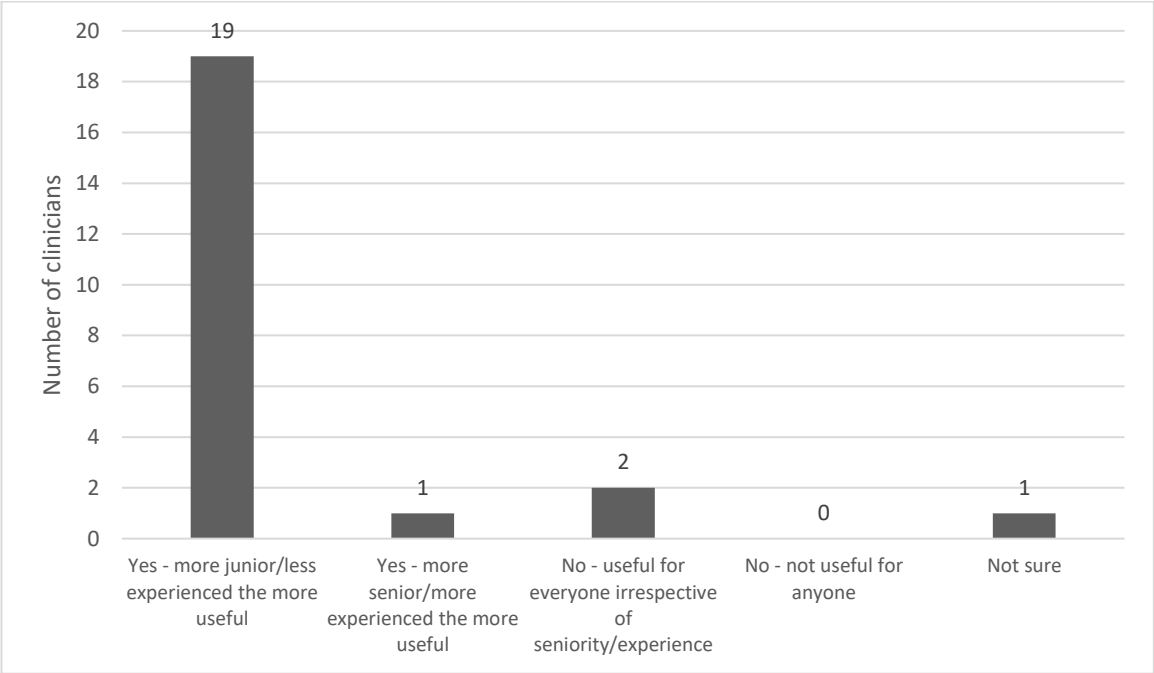
78.3% of respondents felt a CDST could be beneficial in this setting.

3.4.4.6 Do you think a clinical decision support tool would be used routinely by doctors when diagnosing right iliac fossa pain (in addition to their normal assessment)?



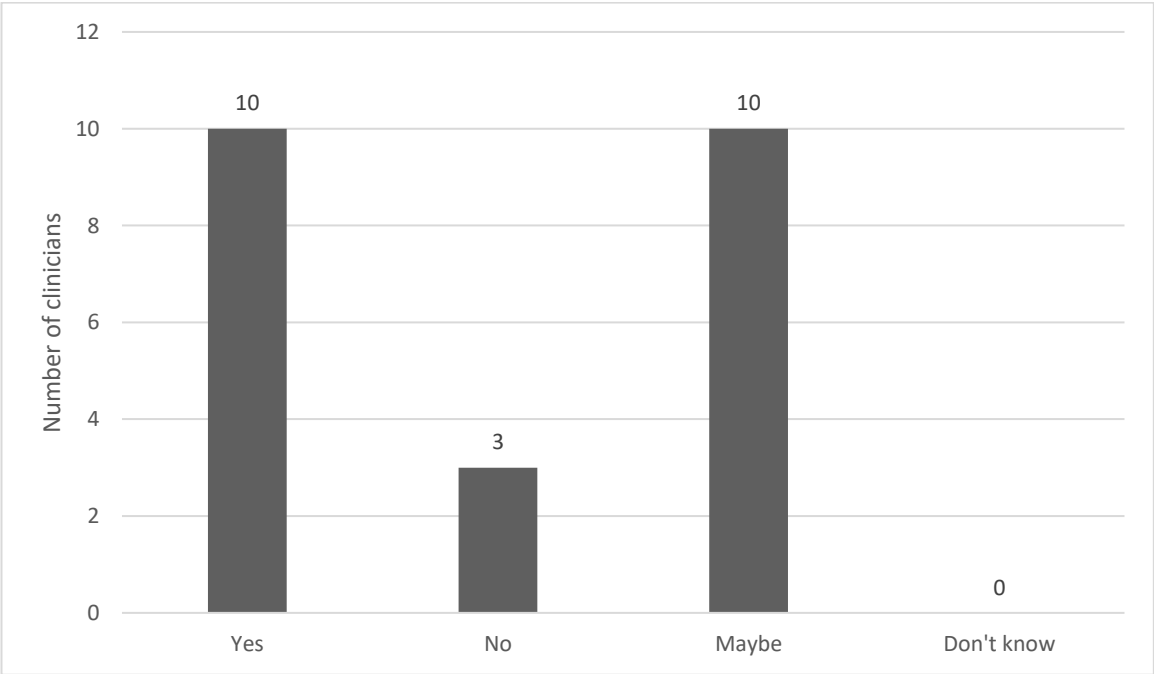
100% of respondents felt that at a minimum some clinicians would use a CDST some of the time.

3.4.4.7 Do you think the experience/seniority of the doctor affects how useful a clinical decision support tool would be?



82.6% of respondents felt the more junior or less experienced a clinician, the more useful they would find a CDST. There were a variety of views with a few respondents also thinking that more experienced clinicians would also benefit.

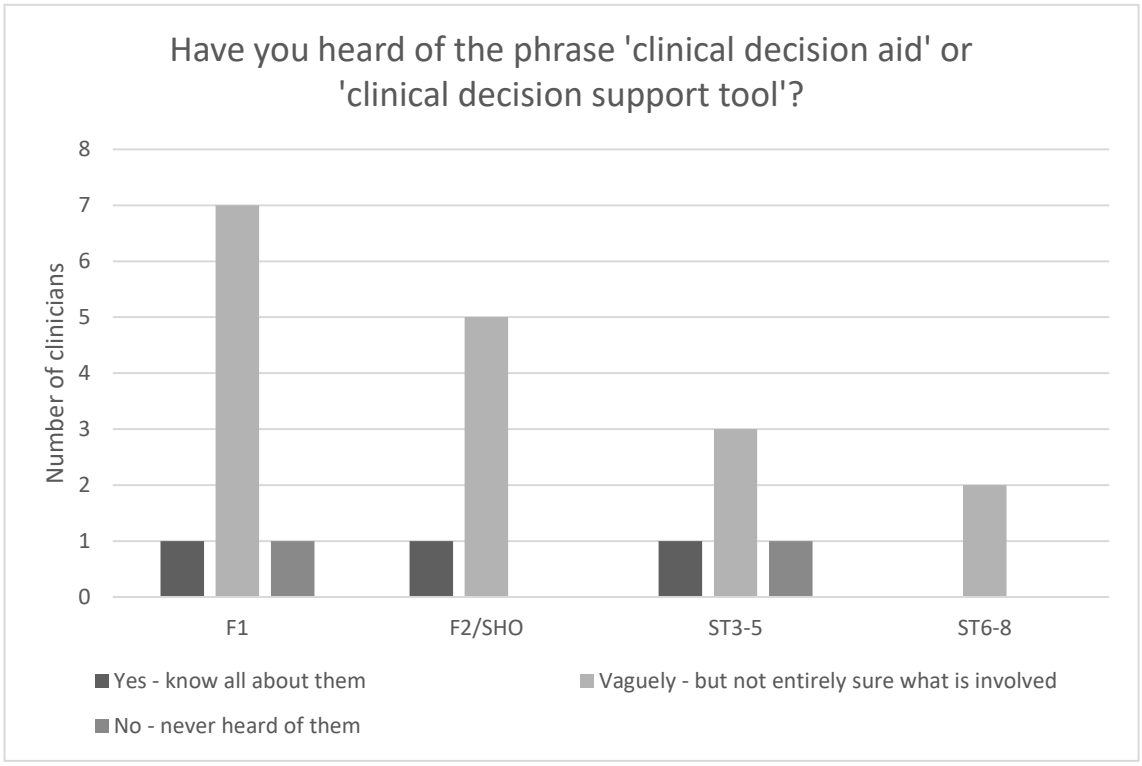
3.4.4.8 Do you think there is likely to be any benefit to patients if a clinical decision support tool is used in conjunction with their normal assessment?

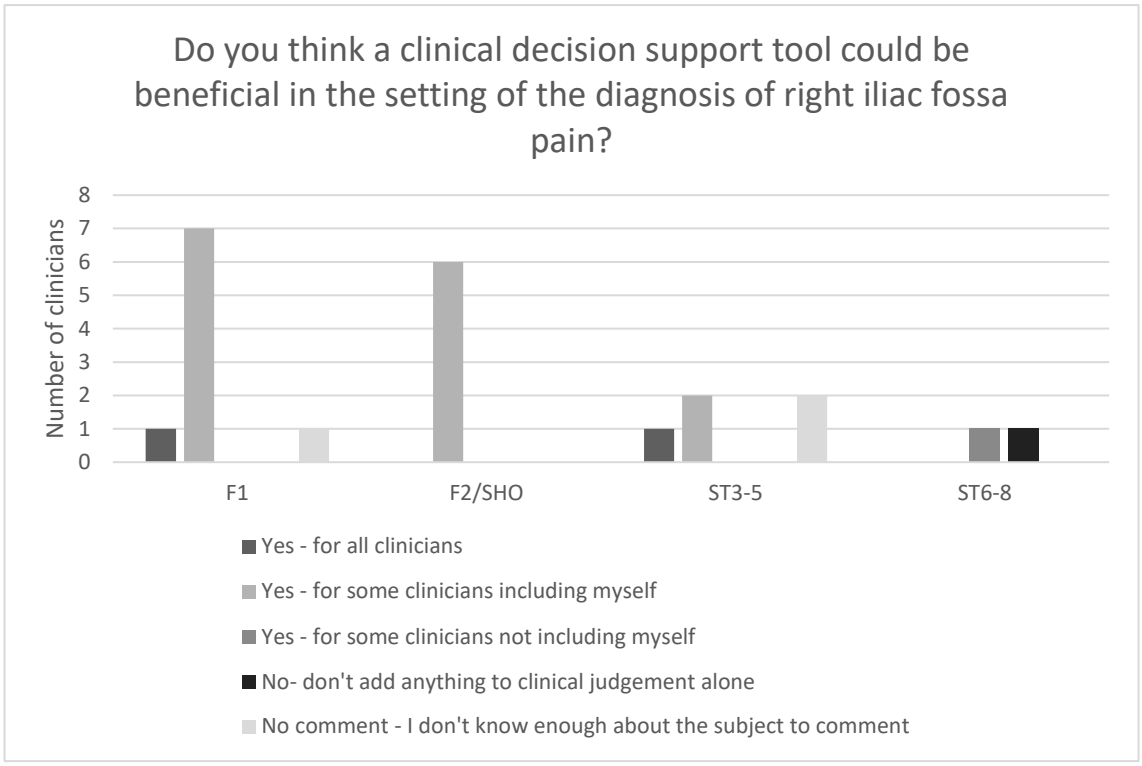


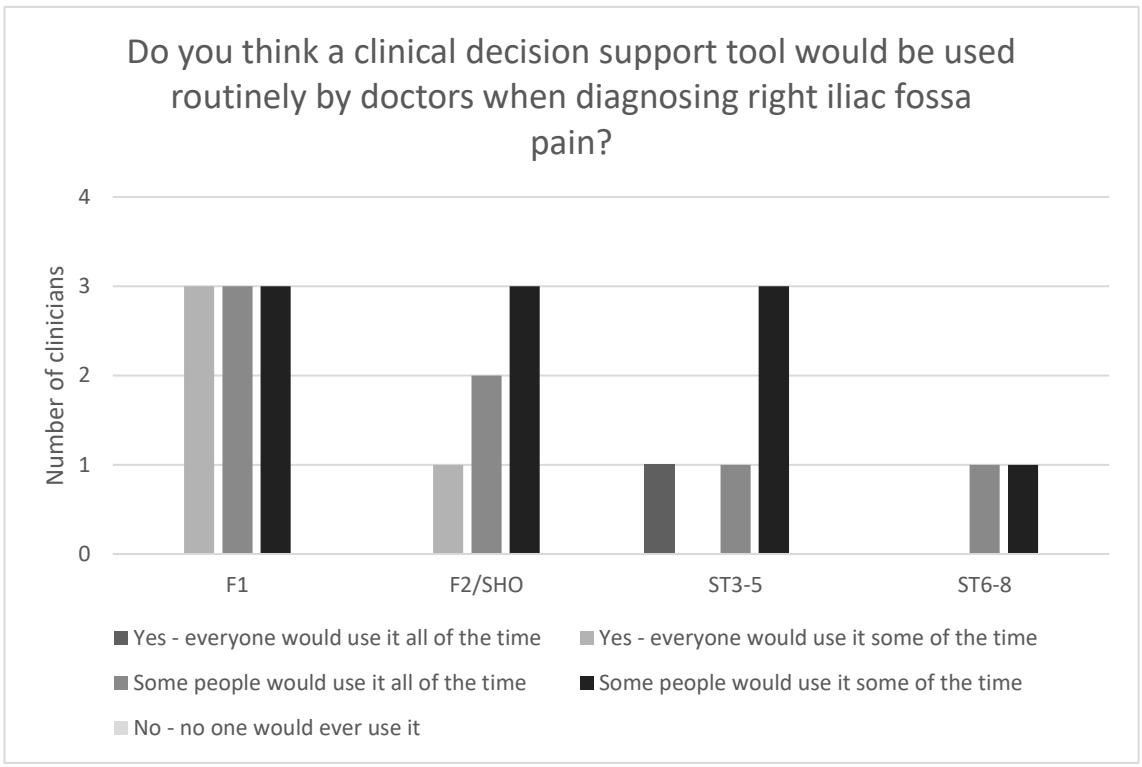
87% of respondents felt that there would or there may be a benefit to patients if a CDST was used in this setting.

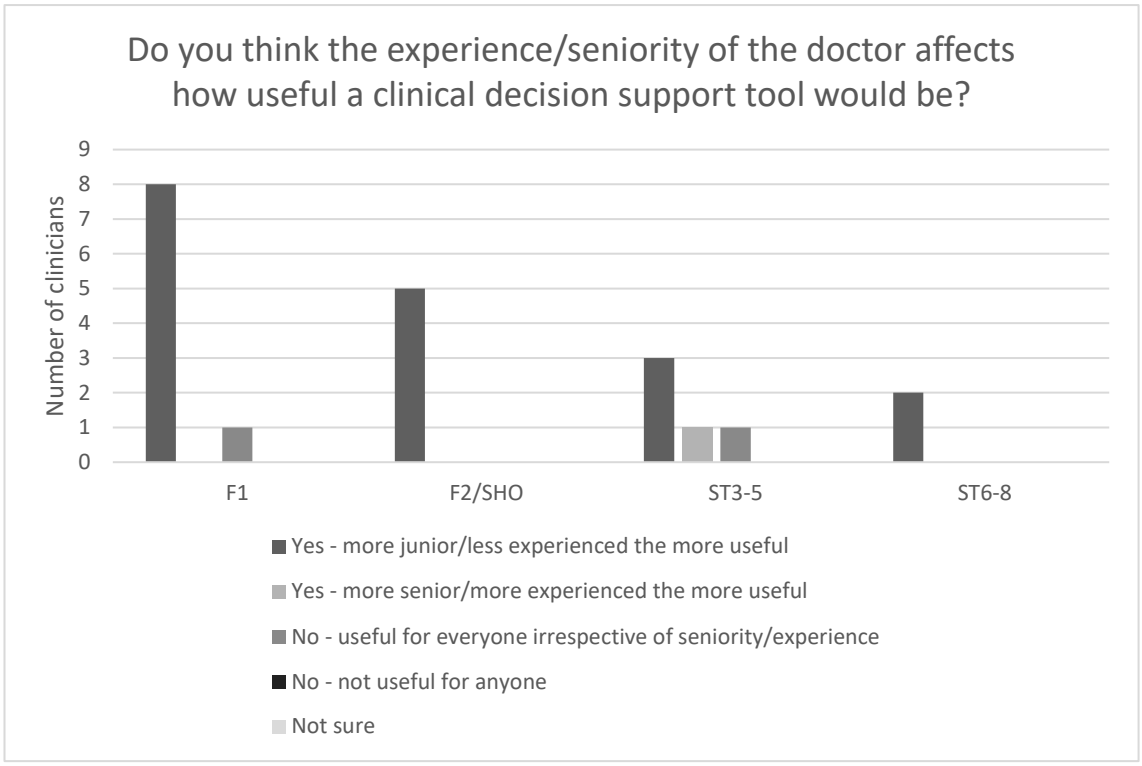
3.4.5 Answers stratified by grade of clinician

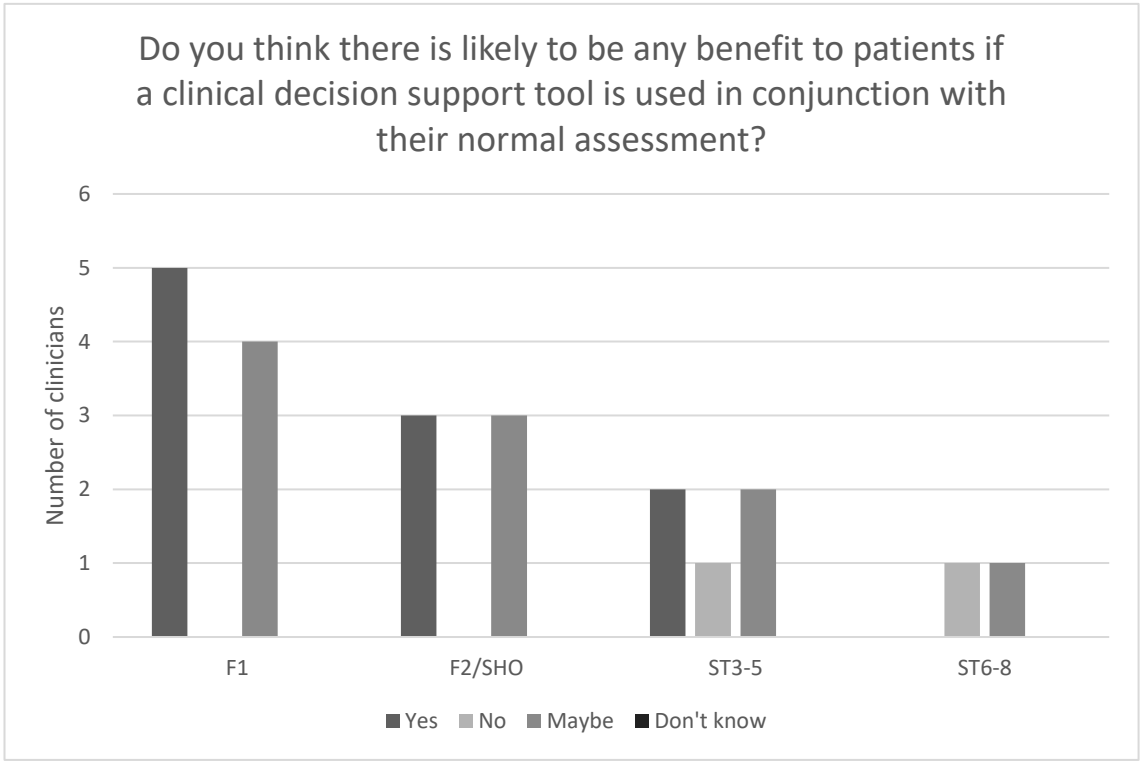
Given that this intervention was focused particularly on less experienced clinicians it was important to break down the views expressed in the survey by the grade of the respondent. For each question of the survey the following histograms depict the answers stratified by grade of respondent.




Do you think a clinical decision support tool could be beneficial in the setting of the diagnosis of right iliac fossa pain?
Number of clinicians
0
1
2
3
4
5
6
7
8
F1
F2/SHO
ST3-5
ST6-8
Yes - for all clinicians
Yes - for some clinicians including myself
Yes - for some clinicians not including myself
No- don't add anything to clinical judgement alone
No comment - I don't know enough about the subject to comment


Do you think a clinical decision support tool would be used routinely by doctors when diagnosing right iliac fossa pain?
Number of clinicians
0
1
2
3
4
F1
F2/SHO
ST3-5
ST6-8
Yes - everyone would use it all of the time
Yes - everyone would use it some of the time
Some people would use it all of the time
Some people would use it some of the time
No - no one would ever use it





3.4.6 **Free text question**

The final question in the survey:

What areas in the diagnosis and management of patients presenting with right iliac fossa pain would you most appreciate guidance or clarification of guidelines on? For example: when to image, when to laparoscope, when to watch and wait, when to discharge etc?

The following free text answers were written by respondents:

- All of the above mentioned
- There is no substitute for clinical experience! E.g. Even female patients with normal bloods normal USS normal observations will eventually get a diagnostic laparoscopy if they have on-going pain. Otherwise they will be readmitted once discharged with ongoing symptoms. There will always be a question about the appendix and gynae will never accept a patient until this has been removed (and frequently still do not accept the patient!). Some "guidelines" may be of some use to junior members of the team (F2s CT1/2) but otherwise there is no substitute for experience (which usually comes with seniority!)
- imaging v scope in childbearing women
- What to do with mad female patients with RIF pain
- More guidance and clarification on;
    - 1.When to perform a diagnostic Laparoscopy.
    - 2.Guidelines on RIF management when blood tests and ultrasound is normal, but the patient is still complaining of pain which is not controlled by oral analgesia
- All of the above! Have had no formal teaching and on call there isn't much time for teaching from seniors as they're busy (understandably!) so currently it's all a bit of educated guesswork
- When to image
- Imaging versus laparoscope
- Standardisation. I have my plan and rationale, but this may be different to the next persons
- When to laparoscope
- My main concern is the liberal use of CT scanning in RIF. It is understandable in the elderly who may be presenting with more sinister pathology but there have been a few RIFs with good stories and 30 or so years of age who have been CT'd and appendicitis proven when they could have just been laparoscoped. The other slight area of confusion is when to USS
- None
- What to do in cases were investigations (imaging bloods etc) are normal but pain persists
- When to image (CT vs US) - When to discharge - When to administer antibiotics
- Image only if we think it might be another pathology rather than appendicitis. Laparoscope if the pain continues and we exclude others causes of pain including medicals causes. Wait in most of cases Discharge when both doctor and patient is happy

- There is considerable variation in how RIF pain is managed on ASU. This variation mainly stems from which consultant is on call. By standardising a RIF pathway, at least we could audit our progress as a unit
- All of the above plus the urgency of investigations/ treatment
- None
- Role of laparoscopy
- When and what imaging to use
- All mentioned above.

3.4.7 Interpretation of survey results

The results of this survey suggested that >75% of junior doctors would appreciate the availability of a CDST and this number increased to >90% when asking Foundation doctors and SHO grades. They confirmed that a CDST could be useful and would be adopted by the clinicians working on the Acute Surgical Unit.

3.4.8 Influences on the design of the proforma and CDST

The results influenced the initial design of the proforma in the following specific ways:

- Confirmed that the proforma should be aimed generally at the more junior trainees and that there might be some problems with uptake with the more senior trainees
- An imaging flow chart should be provided in the CDST – suggesting what imaging modality to use and when
- Clear suggestions for when imaging or laparoscopy was more appropriate should also be in the CDST

By involving these key stakeholders at this early planning stage, it was hoped that it would increase the use of the tool, increase engagement with the study and overall improve outcomes.

The overwhelming opinions were that clinicians, especially junior ones, wanted some standardisation of investigation and management. They felt there was too much variety in practice especially at a senior level and this left them unsure as to what investigations to initiate. They particularly wanted guidance on imaging pathways including deciding on whether a patient should have imaging or a diagnostic laparoscopy, when and how other specialties should be involved, and which patients could be ambulated or discharged.

3.5 Prototype proforma during pilot study and further changes

After the pilot study the proforma, including the CDST, was reviewed in person with 6 clinicians: 1 F1, 1 advanced nurse practitioner, 3 SHOs and 1 Registrar. These were all clinicians who had used the proforma during the pilot period and volunteered to discuss it further. The interviews, which were conducted on a one-to-one basis involved a discussion of the proforma and the CDST and lasted approximately 10-15 minutes, determined by how much feedback the clinician had to give. The clinician was asked:

1. Overall what did they think of the proforma?
2. Any aspects they would change?

The following changes were made to the proforma and the CDST as a result of these discussions:

- A larger space in the 'Plan' box for free text.
- A dedicated space to include the name of a chaperone in the 'Examination' box
- Bleep numbers added for the suggested referral specialties in the CDST
- Layout of the imaging flow chart in the CDST altered to be more readable

After review with the Lead ASU Consultant two additions were made. Two prompts for the clerking clinician were placed within the 'Plan' box; to remind them to prescribe venous thromboembolic prophylaxis and to ascertain whether the patient was pregnant or not.

With personal reflection the tick box to indicate whether the CDST had been used by the clerking clinician was added in the 'Plan' box.

Chapter 4 The new proforma and clinical decision tool

4.1 Section 1: Clerking proforma

University Hospital Southampton NHS
NHS Foundation Trust

Surgical care group

Right Iliac Fossa Pain Admission Proforma

Name: DOB: Hospital number: Stick patient label here	Admitted by: Bleep: Date: Time:
Referral source: GP / A&E/ Other _____	Consultant:

History:

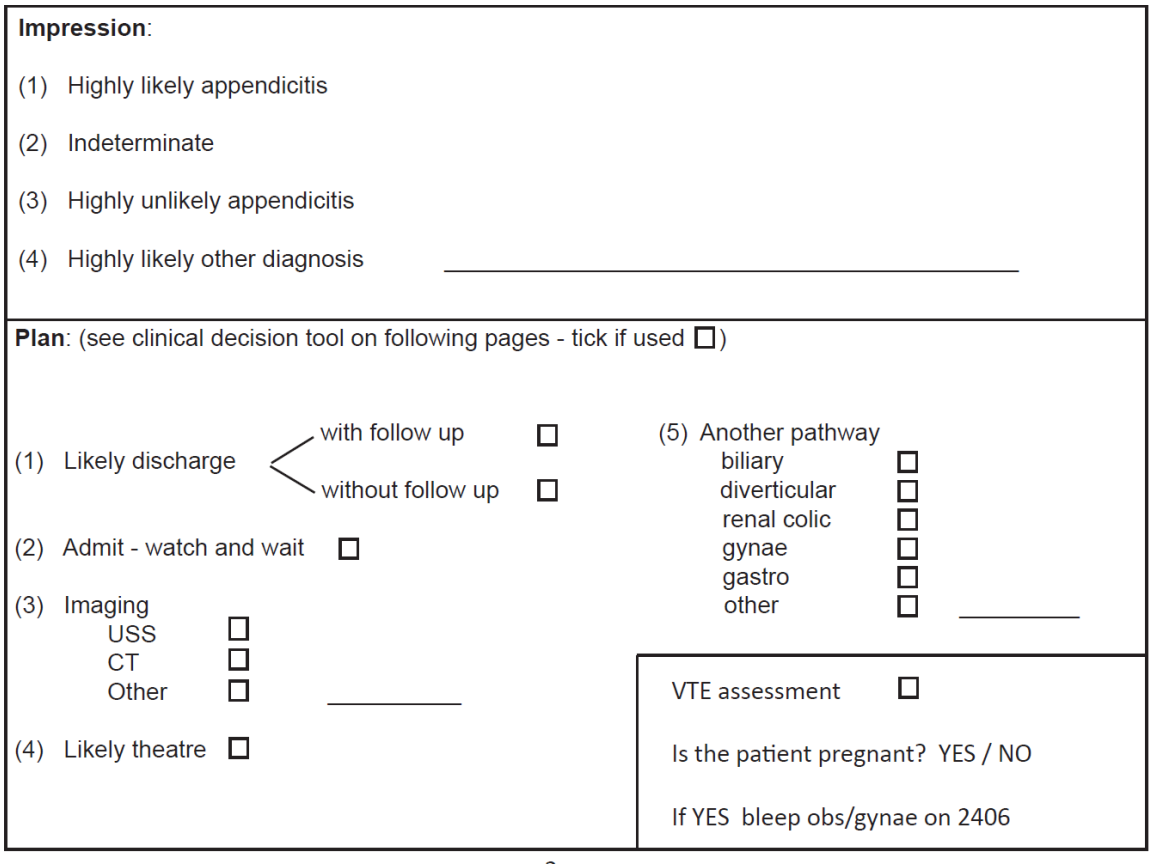
PMH:

1

Drug history:					Allergies:		
Social history:							
Examination:				Weight (kg):	BMI:	MUST score:	
Chaperone: _____							
Temp: Pulse: BP: RR: Sats: on							
PR:							
Urine dip	Leucocytes	Nitrites	Blood	Protein	Ketones	BHCG	MSU sent?

The layout of the clerking section of the proforma was based on the existing Acute Surgical Admissions Proforma.

The next section was developed to guide the clerking doctor in making a plan that would advance the investigation and management of the patients. This aimed to prevent stagnation between the time of junior clerking and senior review.



Impression:

(1) Highly likely appendicitis

(2) Indeterminate

(3) Highly unlikely appendicitis

(4) Highly likely other diagnosis _____

Plan: (see clinical decision tool on following pages - tick if used ☐)

(1) Likely discharge
- with follow up ☐
- without follow up ☐

(2) Admit - watch and wait ☐

(3) Imaging
- USS ☐
- CT ☐
- Other ☐ _____

(4) Likely theatre ☐

(5) Another pathway
- biliary ☐
- diverticular ☐
- renal colic ☐
- gynae ☐
- gastro ☐
- other ☐ _____

VTE assessment ☐

Is the patient pregnant? YES / NO

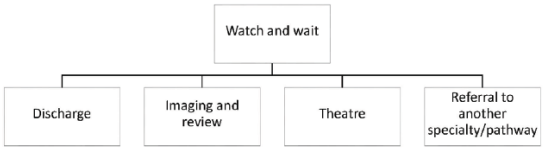
If YES bleep obs/gynae on 2406

4.2 Section 2: Clinical decision support tool

Discharge

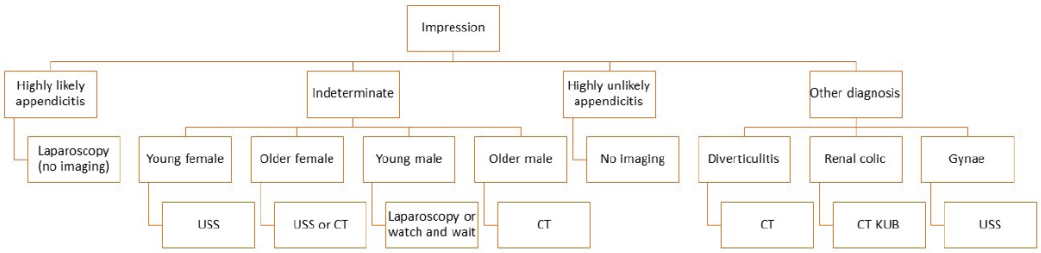
- Atypical history for appendicitis
- WCC and CRP normal
- No other medical reason for admitting patient
- Patient well enough for discharge
- Not requiring opiate analgesia
- All patients should be given 'Abdominal pain information sheet'
- Either discharge or book as ASU ambulatory care patient the following day and give patient relevant information for returning (location, date, time and information sheet with contact number)

Watch and wait



- Atypical for appendicitis
- WCC and CRP normal or only mildly abnormal
- Nominate time or doctor of next review (might be same doctor reviewing patient at later time or more senior doctor to review)
- After further review(s) consider further progression down algorithm

Imaging and review



Theatre

- Typical history and examination with raised WCC and/or CRP

or

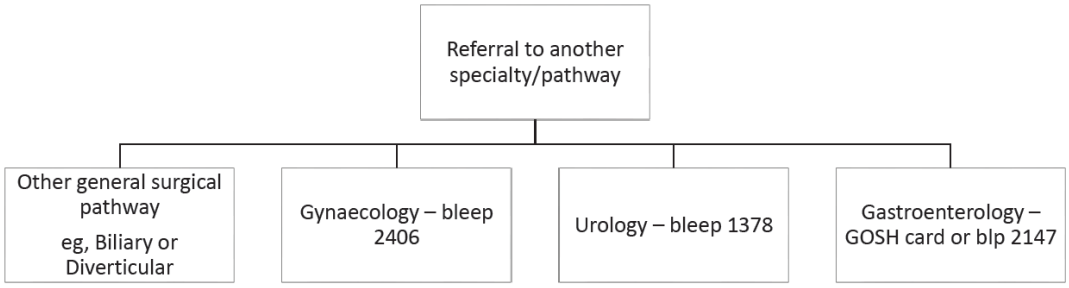
- Imaging suggests appendicitis

or

- Ongoing symptoms with equivocal investigations and imaging

Laparoscopic approach should be first line in all patients unless there is a specific contraindication
Antibiotics administered once definite decision made to take to theatre (Cefuroxime and Metronidazole)

Referral to another specialty/pathway



Name of admitting doctor:	Signature:	Grade:	Bleep:

Each section on the CDST correlated to a ‘Plan’ option from the clerking proforma:

- Likely discharge
- Admit – watch and wait
- Imaging
- Likely theatre
- Another pathway

The contents of the imaging section of the tool correlated with the ‘Impression’ section of the proforma.

4.3 Section 3: Educational content

The educational content section contains a list of likely differentials, key points in history and examination and useful investigations. It then briefly summarises ways to differentiate between appendicitis, diverticulitis, biliary disease and ovarian disease. The last section suggests patients that might be suitable for ambulatory care.

Determining the differential diagnosis

Likely diagnoses

- Appendicitis
- Ovarian pathology
- Diverticulitis
- Non-specific abdominal pain (NSAP)
- Others: IBD (especially terminal ileitis) renal colic, biliary, referred testicular pain, other pelvic pathology

Key points in history

Pain
- Where?
- Time since onset?
- Migratory?

Nausea and/or vomiting?
Loss of appetite?
GI upset – bowels?
Felt feverish?
Any urinary symptoms?
Gynae
- Any previous pathology?
- Where in cycle?
- Any PV discharge/bleeding?

Key points in examination

Observations
- Do they have a temperature?
- Are they tachycardic?

Are they lying still on the bed because it's too painful to move?
Is there abdomen generally soft? Do they have generalised peritonitis (rigid, guarding, percussion tenderness all over)?
Are they tender in the RIF?
- Do they have involuntary guarding?
- Do they have percussion tenderness?

Are they tender anywhere else in the abdomen?

Key investigations

Do female patients have a negative βHCG?
What does the urine dip show?
Bloods
- WCC and CRP – are they raised?
  - NB. WCC rises first (by 12 hours of onset of the pain the WCC may have risen to its maximum and be on the decline)
  - CRP starts to rise only after 12 hours from onset of the pain.

Highly likely appendicitis

If a patient has
- a good history for appendicitis
  - Initially central pain migratory to RIF
  - Usually 1-3 days
  - Loss of appetite
  - May have GI upset (nausea/vomiting or diarrhoea if pelvic infection)
- and consistent examination for appendicitis
  - Tender over McBurneys +/- local or general peritonism
- and raised inflammatory markers with a negative βHCG then they are likely to go to theatre, without imaging, therefore need:
  - Clear fluids and IV fluid (Maintenance – Dex Saline with K+, Resus/replacement – Hartmanns)
  - G&S (and clotting if relevant)
  - Senior review for a definitive decision
  - To be booked and consented

Possible diverticulitis

In middle aged or older patients (or some younger patients) a CT is appropriate if you suspect diverticulitis is a potential diagnosis or an underlying malignancy (red flag symptoms include anaemia, weight loss, PR blood). Diverticular disease increases in frequency with age but is seen occasionally in people in their 30s and 40s. Patients may get right sided symptoms from right colon diverticulitis or a sigmoid colon flopping onto the right side of the abdomen.

Possible biliary

If the patient has a history and examination consistent with right-sided pain but it is difficult to distinguish whether it is upper or lower then consider an USS to look at both RUQ and RLQ. (NB. Looking at LFTs may help they can easily still be normal in biliary colic or cholecystitis).

Possible ovarian

If a young woman has
- a good history for ovarian/gynae pathology
  - sudden onset, low pelvic pain, no loss of appetite, (consider position in menstrual cycle) or any PV discharge
- has an indeterminate examination
  - Non-tender or tender but no peritonism in RIF
- has nil or minimal rise in inflammatory markers

consider an USS (don't worry about whether to refer for a TV as well as a TA ultrasound, the radiologist/sonographer will decide what's appropriate) – make sure you fill in the card appropriately asking a specific question eg ?ovarian cyst accident or evidence of PID NOT ?appendicitis.

Patients potentially suitable for ambulatory care

In patients who
- have a poor history for either appendicitis, ovarian pathology or diverticulitis, and
- are either non-tender / mildly-tender on examination and
- have normal inflammatory markers

no imaging is immediately indicated. Options are 'watch and wait' in hospital or discharged and reviewed in ASU clinic the next day.
- If you have a patient suitable for this pathway they need to be given an abdominal pain information sheet and given written information concerning the date, time and location of their appointment.
- You need to write their discharge summary making it clear they were well enough to go home, that it is unlikely that they have appendicitis but will be reviewed the next day.
- Alert a senior early so they can make the final decision promptly about discharge.

4.4 Final section: Senior review and Post take ward round.

The documentation is concluded with the senior review and post take ward round sections which are unchanged from the existing proforma.

Senior review:			
Name:	Designation:	Date:	Time:
Summary:			
Radiology/ECG/urine results:			

Hb	
WCC	
Plts	
CRP	
INR	
Na	
K	
Urea	
Creat	
Pro	
Alb	
Bili	
AlkP	
ALT	
eGFR	
Amy	
PSA	
Trop	

Working diagnosis:						
Plan:						
Current allowed intake:	NBM	sips	60ml/hr	CFF	free fluids	Diet + fluids
Other (specify):						
Name:		Bleep:		Signed:		

5

Chapter 5 Factors affecting the diagnostic pathway of patients presenting with RIF pain

5.1 Introduction

Right iliac fossa (RIF) pain is the most common presentation to the acute surgical take (7,8) and acute appendicitis is the most common emergency surgical operation (9,10).Therefore any improvement in the pathway for this cohort of patients will have a proportionally large impact on emergency general surgery overall for both patients and clinicians.

Common pathologies causing RIF pain include appendicitis, acute gynaecological pathology (ovarian cyst rupture, mid cycle pain, tubo-ovarian sepsis, ovarian torsion), diverticulitis, renal calculi and mesenteric adenitis. A significant proportion of patients presenting with RIF pain are discharged with a diagnosis of non-specific abdominal pain (NSAP) (11). The pathologies underlying RIF pain range in severity and the need for intervention. Both diagnosis and management can be complicated, especially with atypical presentations of the causative pathologies. General surgical literature looking at RIF pain is predominantly concerned with appendicitis and is often retrospective, identifying those patients who have had an appendicectomy and examining the diagnostic process prior to theatre. This has been identified as a flaw and the need to examine all patients with RIF pain identified (12). This study looks at all patients presenting with RIF pain, follows them prospectively and considers all eventual diagnoses.

The usual pathway of a patient presenting with RIF pain in the UK is as follows:

1. Referral to the on call general surgeons from either the emergency department, primary care or from another medical specialty within secondary care
2. Initial assessment and clerking often performed by a junior surgical clinician
3. Initiation of basic investigations including bloods and radiological imaging
4. Review by a senior clinician with possible addition or change in the diagnostic investigations
5. Decision for discharge, further investigation, active observation, non-operative or operative management.

The aim of this study was to investigate the factors affecting the diagnostic pathway of patients presenting with RIF pain between stages 2-4 and with the implementation study to see if stage 2 and 3 could be positively influenced.

5.2 Methods

All patients referred to the Acute Surgical Unit with RIF pain were potentially included in this research. Exclusion criteria were patients aged younger than 16 years and patients with a previous appendicectomy.

Data from all patients referred to the Acute Surgical Unit during the three stages of the study (initial data collection, pilot study and implementation period) was analysed.

Data was collected from the patient notes and the hospital electronic patient data systems.

Data analysis was conducted in Microsoft Excel® 2016 and statistical analysis in GraphPad Prism® 7.04. Continuous variables are described as means when normally distributed or median when non-normally distributed. Comparison of continuous variables was by unpaired t tests or Mann-Whitney U tests, as appropriate. Categorical data are reported as absolute values and percentages where appropriate, and differences were analysed by χ^2 tests. Statistical uncertainty was estimated using 95% confidence intervals and significance was attributed at the 5% level.

5.3 Results

605 patients were included in the study. See Figure 7 for the details of excluded patients.

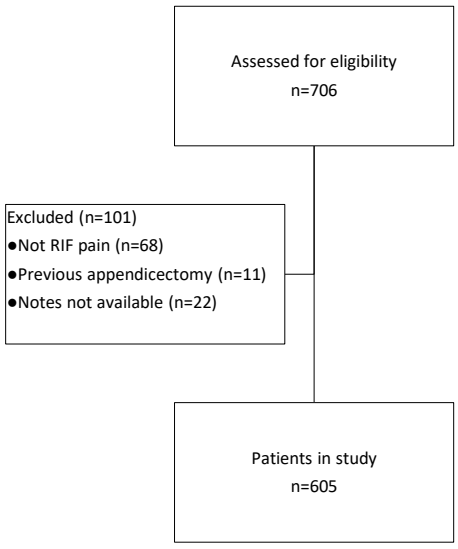


Figure 7 Consort diagram for study participants

5.3.1 **Demographics**

Table 7 shows the demographics of the entire cohort of the study. Details on age, BMI, gender, co-morbidities and source of referral were collected.

Table 7 Demographics

	Patients	
	n	**%**
Total number of patients	605	
Age		
<30	311	51.4
≥30	294	48.6
BMI		
<18.5	14	0.66
18.5-24.9	233	38.5
25.0-29.9	206	34.0
≥30	132	21.8
missing	20	3.30
Gender		
Male	209	34.5
Female	396	65.5
Charlson index		
0	443	73.2
1	64	10.6
2	45	7.44
3	26	4.30
4	13	0.50
>4	13	0.50
missing	1	0.17
Referral source		
ED	269	44.5
GP	328	54.2
Other	8	1.32

51% of patients were aged under 30 years old. There is a decreasing proportion of referrals with increasing age (Figure 8). 39% patients had a normal Body Mass Index (BMI). 35% of patients were male. 73% of patients had no co-morbidities on the Charlson co-morbidity index. 45% of referrals were from the emergency department and 54% from primary care. The other referrals were from cruise ship doctors and other hospital specialties.

5.3.1.1 Age

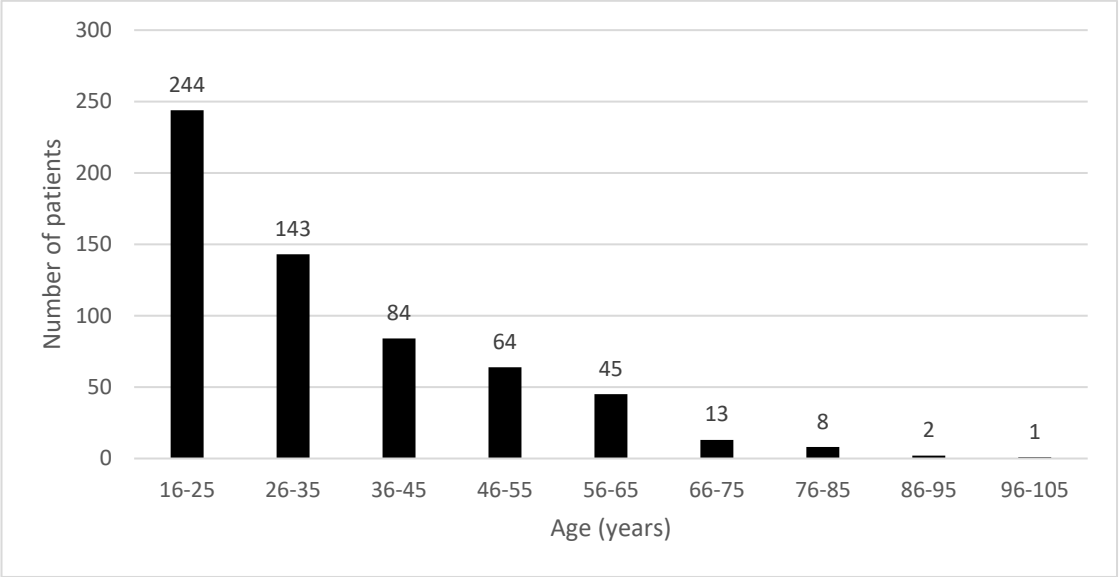


Figure 8 Age demographics of cohort

5.3.2 Diagnoses

5.3.2.1 Provisional diagnoses

Provisional diagnoses were those written by the clerking doctor based on clinical impression after history and examination usually without the results of any investigations such as bloods or radiological imaging. In the event of a list or differential diagnoses being documented, the provisional diagnosis was taken as that listed first by the clerking doctor or indicated by the clerking doctor to be most likely (for example underlined, circled or arrowed). When no provisional diagnosis was listed at all then this was also documented.

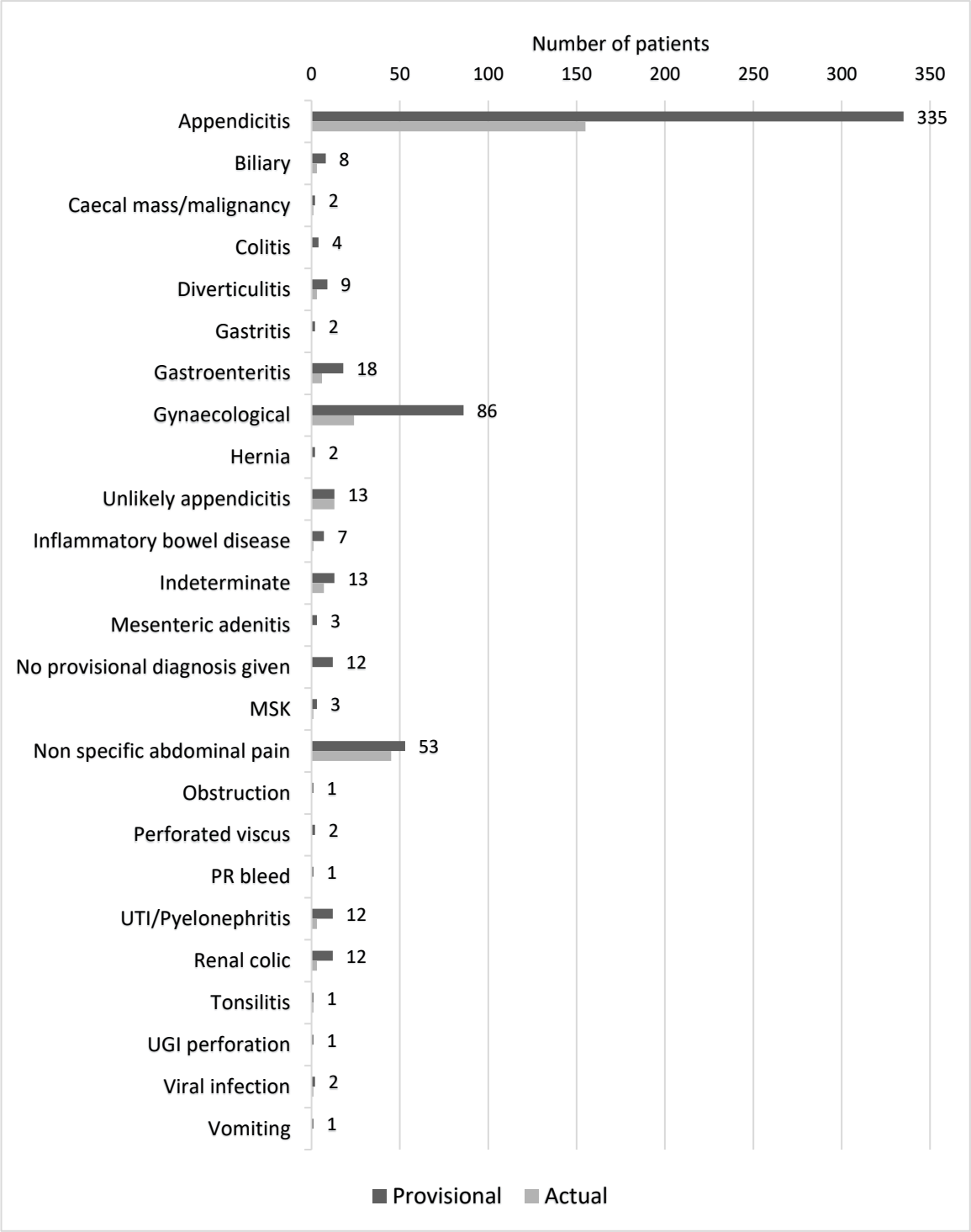


Figure 9 Provisional diagnoses with proportion of correct definitive diagnoses

Figure 9 shows the wide range of provisional diagnoses made with the proportion of each group that went on to have that as a definitive diagnosis. In 12 cases (1.98%) no provisional diagnosis was given.

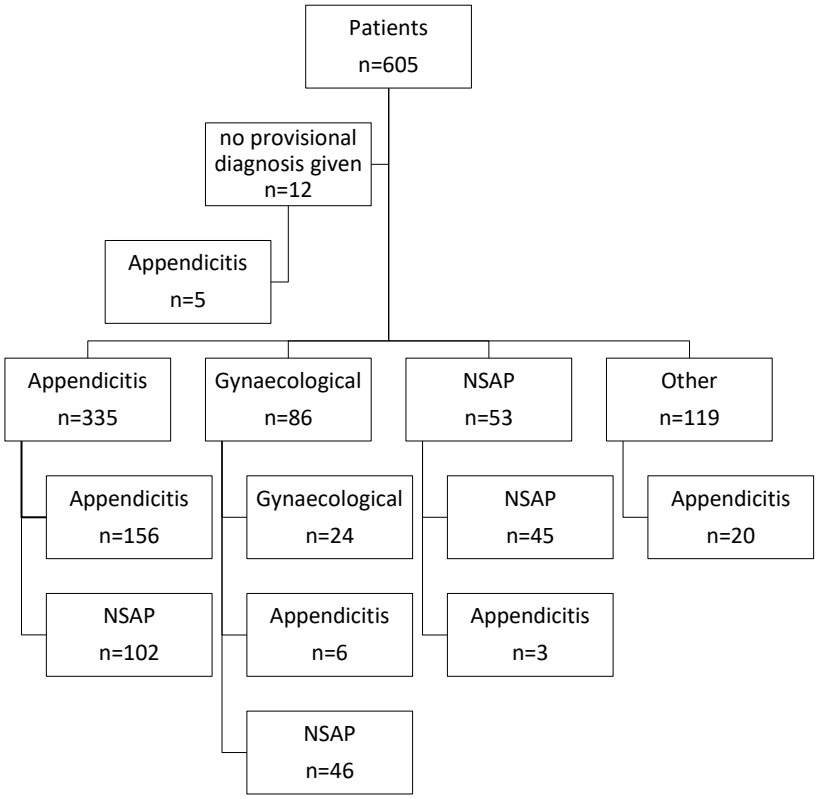


Figure 10 Provisional diagnoses with the associated definitive diagnoses

Figure 10 illustrates the eventual definitive diagnoses categorised by the provisional diagnoses given after clerking. Of the 605 patients referred, after initial assessment only 55.4% were suspected of having appendicitis by the clerking doctor. Of those, 46.6% had a definitive diagnosis of appendicitis. 14.2% were felt likely to have a gynaecological pathology and 27.9% of those did have that diagnosis. Of the patients who were felt to have a gynaecological pathology after the initial clerking, only 6.98% had appendicitis as their definitive diagnosis. 8.76% patients were given a provisional diagnosis of NSAP. In 84.9% of those patients, NSAP was their definitive diagnosis, in 5.66% it was appendicitis. 82.1% of patients with a definitive diagnosis of appendicitis also had a provisional diagnosis of appendicitis. 34 patients (17.9%) who ultimately had appendicitis were thought to have a different pathology after initial clerking.

Table 8 PPV and NPV of provisional diagnoses for determining definitive diagnoses

Pathology	PPV	NPV
Appendicitis	0.47	0.89
Gynaecological pathology	0.28	0.91
NSAP	0.85	0.64

A provisional diagnosis of appendicitis has a positive predictive value of having appendicitis of 0.47. The corresponding negative predictive value is 0.89. The PPV and NPV for gynaecological pathology are 0.28 and 0.91 and 0.85 and 0.64 respectively for NSAP (See Table 8).

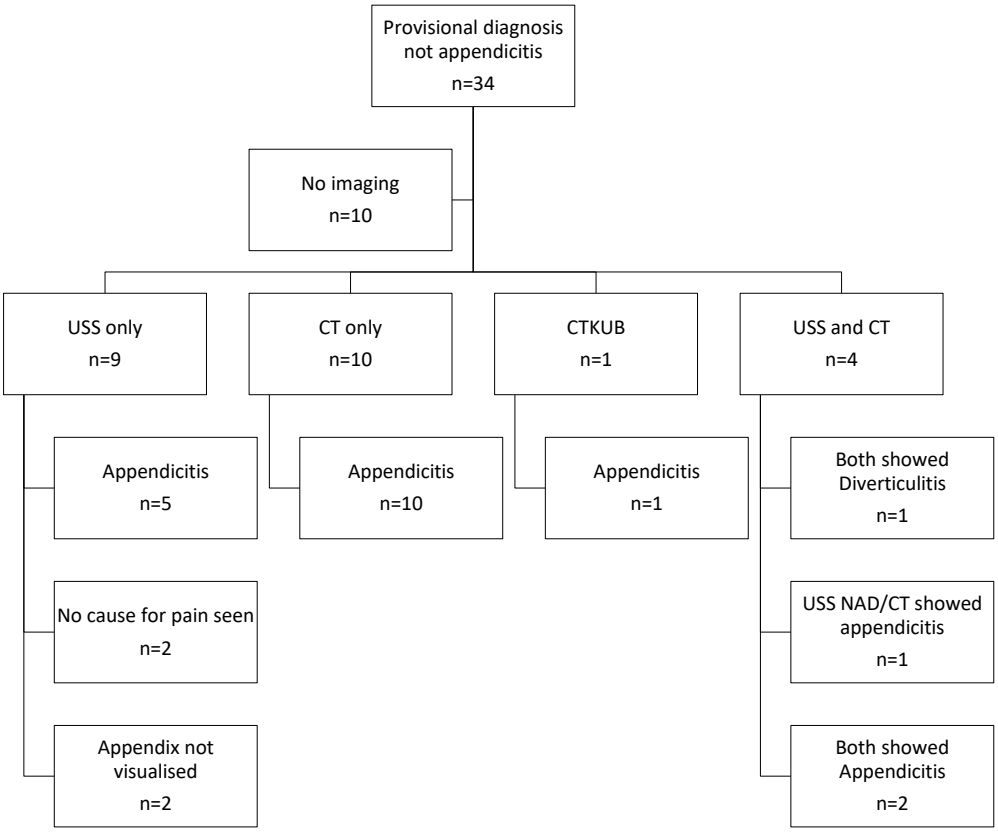


Figure 11 Patients with definitive diagnoses of appendicitis without a provisional diagnosis of appendicitis

Figure 11 shows those patients that did not have a provisional diagnosis of appendicitis but subsequently had a definitive diagnosis of appendicitis. One of the patients where the appendix was not visualised on ultrasound was 23 weeks pregnant. Another patient had both an ultrasound and CT reported as showing diverticulitis but eventually was shown to have appendicitis. The CT scan images were re-reviewed by a Consultant GI radiologist with the knowledge of the operative findings of appendicitis and it was still felt that a report of diverticulitis would have been given from the images alone.

5.3.2.2 Definitive diagnoses

Definitive diagnosis was defined in four ways in decreasing order of importance: as defined by histology; description of operative findings if no specimen was taken; on radiology; and by documented clinical decision by the most senior clinician at patient discharge.

The date and time attributed to the definitive diagnosis were as per the above events. The only additions to these were culture results for urine or stool infections which confirmed clinical diagnoses.

Operation dates, times and details were taken from data inputted by the surgeon into the electronic operation note. Date and time of radiological diagnoses were taken from the Consultant report.

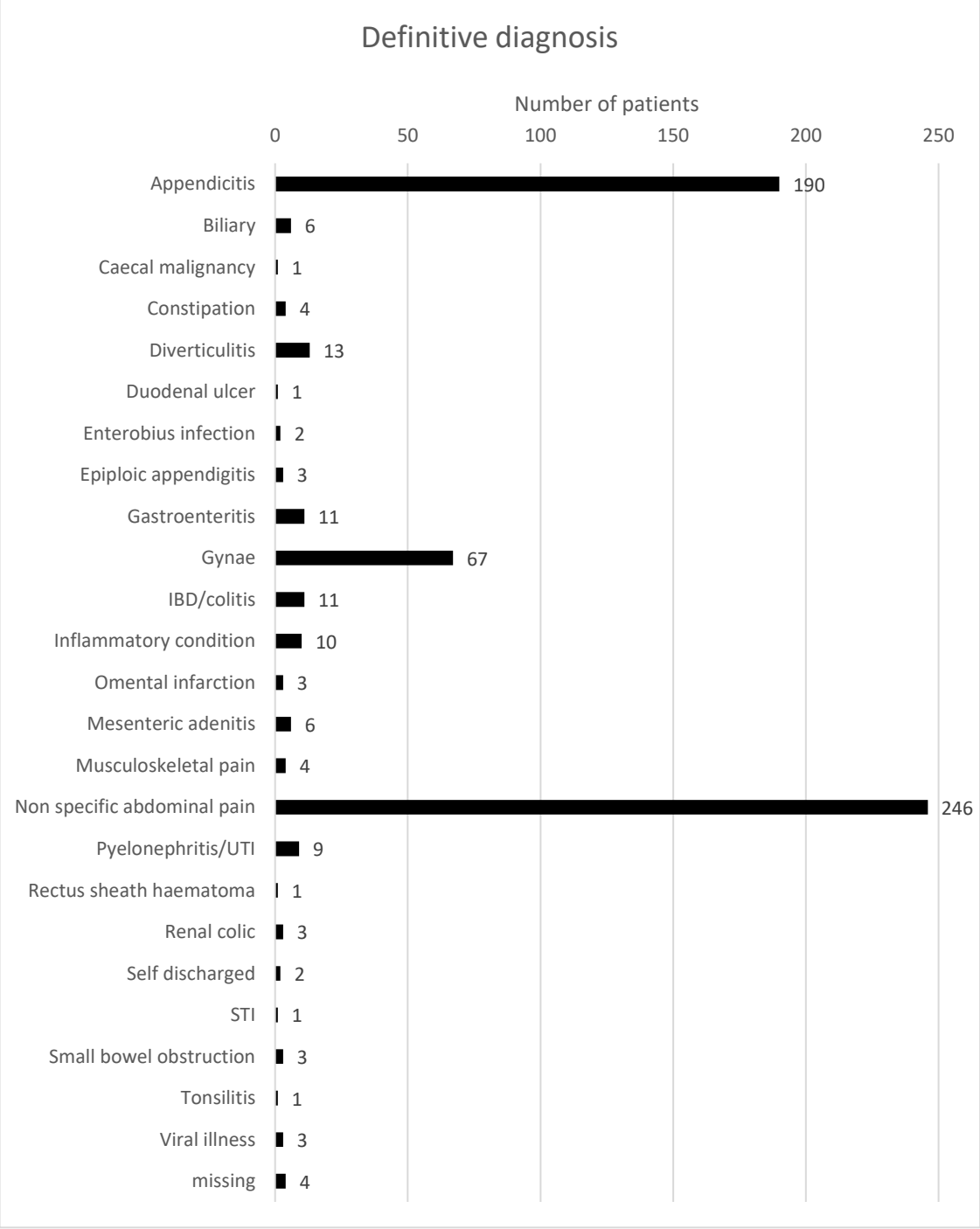


Figure 12 Definitive diagnoses of all patients

See Figure 12 for definitive diagnoses for all patients. The most frequent diagnosis in this cohort was NSAP (40.7%) with appendicitis (31.4%) as the second most common and gynaecological pathology (11.1%) as the third.

5.3.2.2.1 Definitive diagnoses stratified by age (see Figure 13)

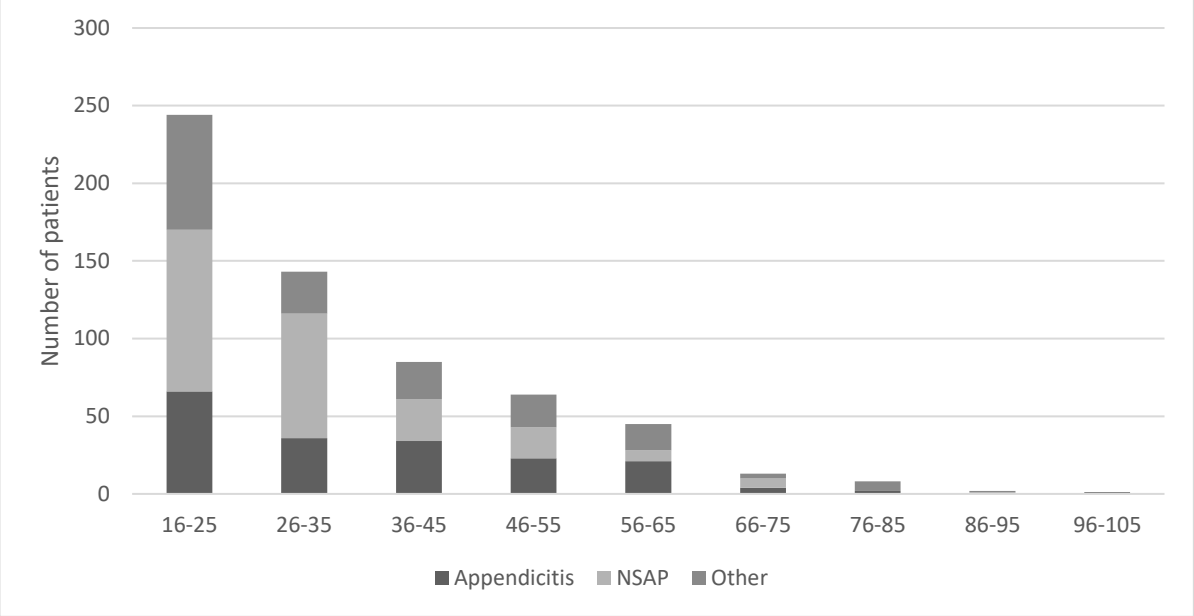


Figure 13 Distribution of diagnoses by age

The incidence of appendicitis trends down with age as does NSAP.

5.3.2.2.2 Definitive diagnoses stratified by gender (See Figure 14)

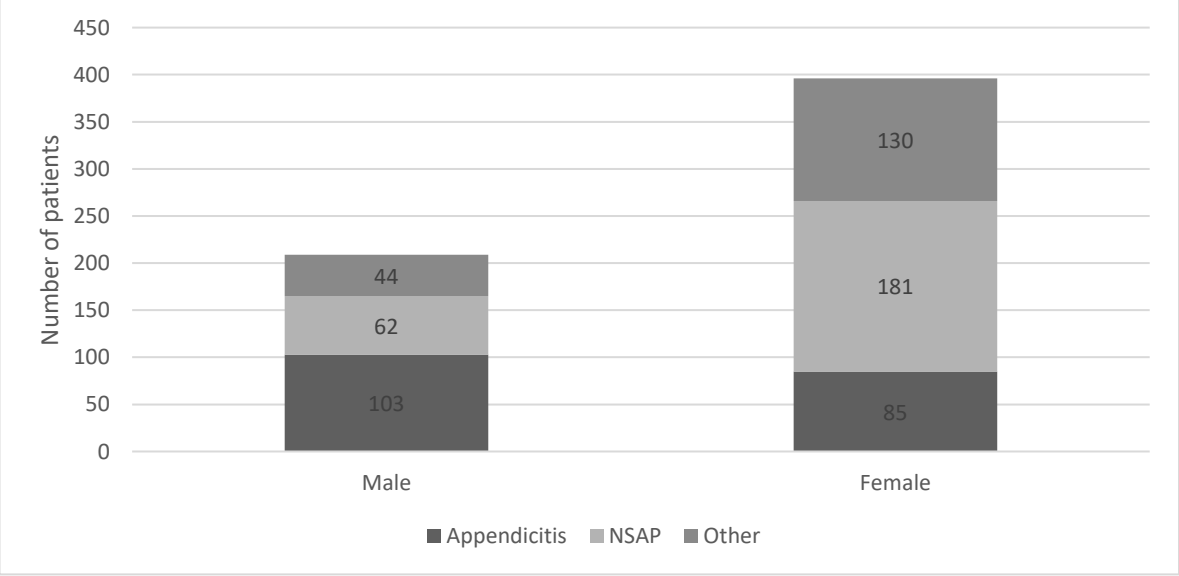


Figure 14 Distribution of diagnoses by gender

49.3% of male patients referred with RIF pain had a definitive diagnosis of appendicitis compared to 21.5% of female patients. In contrast, 29.7% of male patients had a definitive diagnosis of NSAP compared to 45.7% of female patients. Other diagnoses were found 21.1% and 32.8% in males and females respectively. The likely reasons for this are discussed in Chapter 4.1.

5.3.2.3 Definitive diagnoses stratified by Referral source

Most referrals were received from the emergency department or from primary care. The small minority came from internal referrals from within the hospital (gynaecology, urology and medicine) and due to our unit's geographical location, from cruise ship medical teams (See Figure 15).

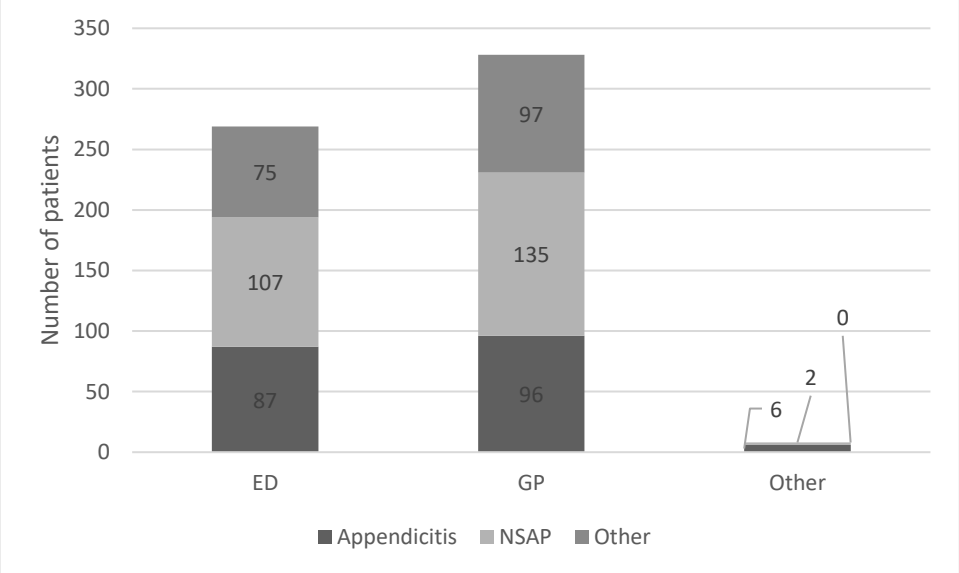


Figure 15 Definitive diagnosis by referral source

32.3% of referrals from the Emergency Department with RIF pain had a definitive diagnosis of appendicitis compared to 29.3% from primary care and 75% from other sources. Many referrals from other specialties in the hospital are referred after imaging has already confirmed appendicitis.

39.8% of referrals from the Emergency Department with RIF pain had a definitive diagnosis of NSAP compared to 41.2% from primary care and 25% from other sources.

There is no difference in likelihood of eventual diagnosis of either appendicitis (p=0.4235) or NSAP (p=0.7384) when referral is from either the emergency department or primary care.

5.3.3 **Timings**

All timings were calculated in hours from time of admission to the ASU until defined time points as documented in the patient's notes.

5.3.3.1 Time from admission to outcome measures (See Table 9)

Table 9 Time from admission to outcome measures

	Time in hours – median	p value
To time of clerking		
All patients	1	
Appendicitis	1	0.5969
NSAP	0.8	
To time of senior clinician review		
All patients	2.5	
Appendicitis	2.5	0.4685
NSAP	2.25	
To time of documented definitive diagnosis		
All patients	16.75	
Appendicitis	12.5	*0.0143**
NSAP	17.5	
To time of theatre (where applicable)		
All patients	19	
Theatre for suspected appendicitis	19	
Appendicitis	17	*<0.0001***
Not appendicitis	27	
Length of stay (in days)		
All patients	2	
Appendicitis	3	*<0.0001****
NSAP	1	

The median time taken from admission to clerking for all patients was 1 hour. The median time taken from admission to senior review was 2.5 hours. There was no significant difference in time taken from admission to clerking or senior review when comparing patients with an eventual definitive diagnosis of appendicitis and NSAP.

The median time taken from admission to documentation of definitive diagnosis for all patients was 16.75 hours. This time difference was significantly shorter in patients with an eventual definitive diagnosis of appendicitis (12.5 hours) compared to those with a definitive diagnosis of NSAP (17.5 hours).

The median time taken from admission to theatre for patients with suspected appendicitis was 19 hours. The time taken from admission to theatre was significantly shorter in patients who subsequently went on to have a diagnosis of appendicitis (17 hours) compared to those who didn't (27 hours).

The total length of stay (including readmissions) was 2 days. The length of stay for patients with a definitive diagnosis of appendicitis was significantly longer (3 days) then patients with a definitive diagnosis of NSAP (1 day).

5.3.4 **Theatre**

273 patients were taken to theatre.

There were four groups of patients who went to theatre.

1. Those who had suspected appendicitis
2. Those who had another general surgical pathology
3. Those who were taken to theatre by another specialty other than general surgery
4. Those who were taken to theatre in another institution

The number of patients in each of those groups and their definitive diagnoses can be seen in Figure 16.

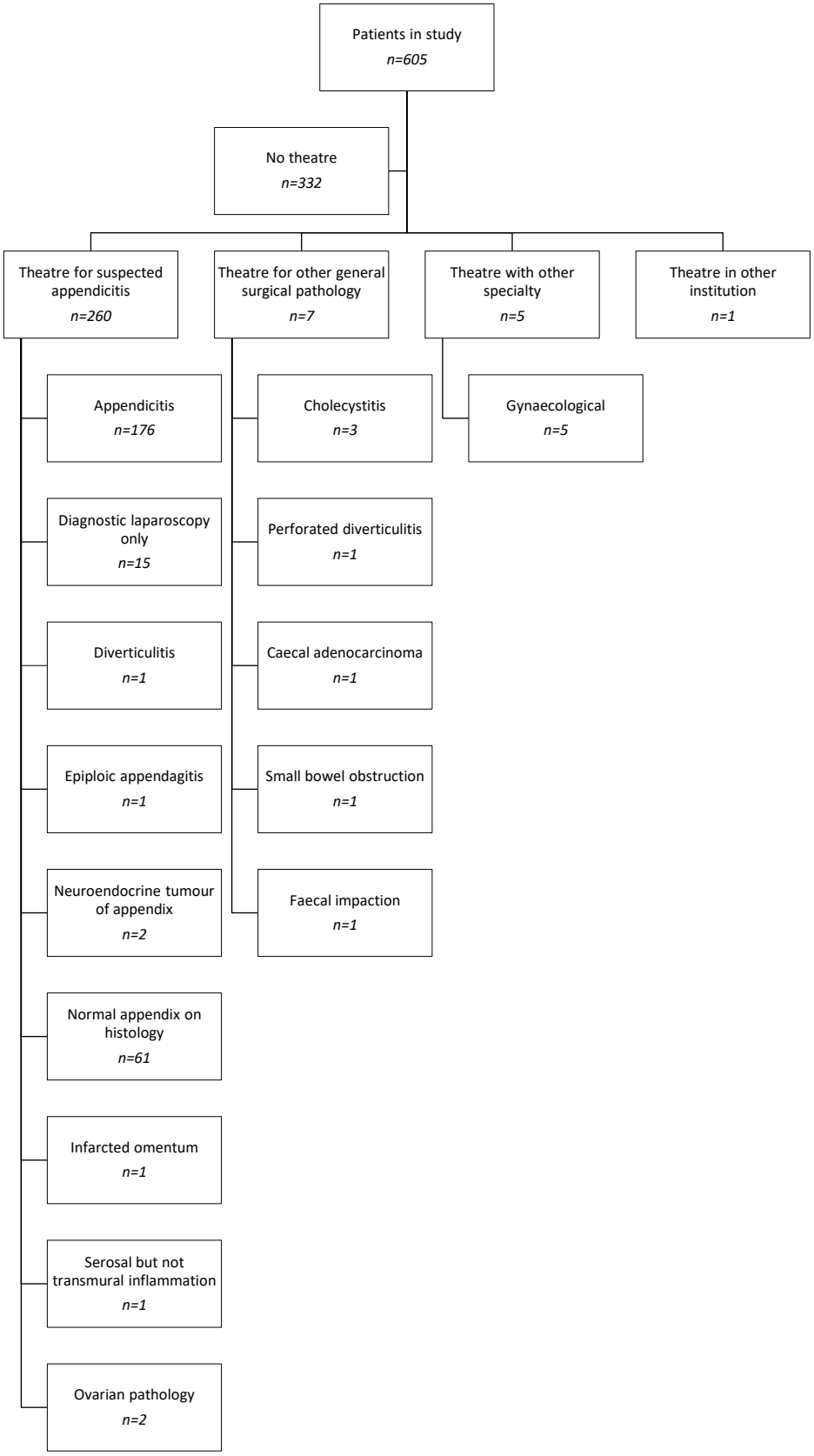


Figure 16 Definitive diagnoses of patients taken to theatre

260 patients (43.0%) went to theatre for suspected appendicitis. Of those, 176 patients (67.7%) had appendicitis. 61 patients had a normal appendix on histology, therefore the negative appendicectomy rate was 23.5%. Other abnormalities of the appendix included two

neuroendocrine tumours and one appendix that had serosal but not transmural inflammation. 15 patients (5.77%) had a diagnostic laparoscopy only, no pathology seen, and their appendix left insitu. Four patients had other pathology on laparoscopy (epiploic appendagitis, infarcted omentum and ovarian pathology). Five patients had open procedures (three laparotomies and right hemicolectomies (for appendicitis) and two open appendicectomies). There were 12 laparoscopic converted to open appendicectomies.

Seven patients went to theatre for another general surgical pathology other than suspected appendicitis (cholecystitis, perforated diverticulitis, caecal adenocarcinoma, small bowel obstruction and faecal impaction).

Five patients were transferred to the care of the gynaecologists before going to theatre and one patient with a suspected appendicitis was transferred to the private sector.

5.3.4.1 Theatre by gender

Table 10 Theatre stratified by gender

	Male n	**%**	**Female** n	**%**	*p value*
Total number of patients in study	209		396		n/a
To theatre for suspected appendicitis	123	**58.9**	139	**35.1**	*<0.0001****
Appendix removed	118	**95.9**	126	**90.6**	0.1404
Appendicitis on histology	99	**83.9**	77	**61.1**	*0.0003****
Other abnormal pathology of appendix	2	**2.54**	1	**0.79**	n/a
Negative appendicectomy rate		**14.4**		**36.5**	*<0.0001****

Male patients referred with RIF pain are statistically significantly more likely to be taken to theatre for suspected appendicitis, have appendicitis on histology and have a lower negative appendicectomy rate (Table 10).

5.3.5 **Morbidity and mortality**

There was no post-operative mortality. Post-operative morbidity for patients taken to theatre with suspected appendicitis was 6.5%. There was no post-operative morbidity for patients taken to theatre for other pathologies. The post-operative morbidity for patients with a definitive diagnosis of appendicitis was 7.88%. The post-operative morbidity for patients with a definitive diagnosis other than appendicitis was 4.76%. This was not a statistical difference (p=0.5934).

260 patients went to theatre for suspected appendicitis. 243 patients (93.5%) had no deviation from the normal post-operative course. Two patients were discharged without a diagnosis of appendicitis and were subsequently readmitted requiring appendicectomy for acute appendicitis. 566 (93.6%) of patients did not reattend after they were discharged. 39 patients reattended for review or were admitted. Three patients represented with pelvic collections. Two required interventional radiology guided drains and one required treatment with antibiotics only.

The post-operative morbidity for patients taken to theatre with suspected appendicitis of 6.5% is similar to that of McCarten et al who reported a post-operative morbidity of 8.6% in a similar study. There was no difference in the post-operative morbidity between patients whose definitive diagnosis was appendicitis and those whose wasn't. The missed appendicectomy rate was 1.04% with two patients with appendicitis being initially discharged without a diagnosis of appendicitis.

5.4 Discussion

This is the largest study to date looking at all patients presenting with RIF pain as acute general surgical admissions. It gives a more complete picture than looking retrospectively at patients who have had an appendicectomy (12). There is very little literature that reports on this whole cohort of patients presenting with RIF pain.

About half of the presenting patients were aged below 30 years in age. 65% were female and three quarters of the cohort had no co-morbidities. There were similar numbers of referrals from the Emergency Department and Primary Care. The age distribution and male to female ratio is similar to other studies by McCarten, Andersson and Scott (12,93,97). No data was available in these studies on referral source or co-morbidities for comparison.

A provisional diagnosis generally represents a clinical assessment based on history and examination. After clerking, just over 50% of patients were felt to have appendicitis. History and examination is important. Korner (32) showed that migratory pain and nausea or vomiting could

be independent predictors for a diagnosis of appendicitis. Rasmussen (33) listed migratory pain and peritonism as supporting the diagnosis of appendicitis. Signs and symptoms make up a large proportion of the elements in scoring systems.

This study found that the provisional diagnosis (as a surrogate marker for clinical assessment based on history and examination) was a bad discriminator for diagnosing appendicitis and gynaecological pathology with poor positive predictive values although much better as a 'rule out' marker with good negative predictive values for both. The reverse was true for a diagnosis of NSAP.

A number of studies have shown that the most effective pathway for patients with RIF pain is to use a comprehensive clinical assessment to establish a group of patients who have an equivocal diagnosis and therefore need imaging, as opposed to those who either obviously need theatre or those that can be discharged (68,83,128) This is in contrast to routine use of imaging for all patients (64).

The most common definitive diagnosis in this study was NSAP at 40.7%. De Dombal (129) first described NSAP as an entity and it is reported as accounting for 13-40% of all acute admissions with abdominal pain (130). This also correlates with the estimation from Poulin (11) that about a third of all patients discharged from surgical units having presented with acute abdominal pain leave with a diagnosis of NSAP. A large proportion of patients with NSAP are not discharged without having had baseline investigations, imaging and sometimes diagnostic operations and this has a cost burden as explored by Raheja (131). Decadt (132) suggested early laparoscopy in this group to improve diagnostic rates. NSAP remains a diagnosis of exclusion.

31.4% patients had a definitive diagnosis of appendicitis. There is variation in the incidence of appendicitis in this cohort across the literature, but our data does fall within this range (see Table 11).

Table 11 Incidence of appendicitis in patients presenting with RIF pain (12,93,97,133)

Paper	**Number of patients in study presenting with RIF pain**	**% with appendicitis**
Andersson 2008 Sweden	502	**35**
Healy 2013 Ireland	94	**42.7**
McCartan 2009 Ireland	302	**39**
Scott 2015	464	**28.4**

UK		
Pearson 2018 *UK*	*605*	***31.4***

Appendicitis is seen more commonly in males than females in this study which correlates with other studies (12,32,97). Unsurprisingly they are significantly more likely to be taken to theatre for suspected appendicitis, have appendicitis on histology and have a lower negative appendicectomy rate. This is also well described (9). NSAP is seen more commonly in females (131). There was no difference in the proportion of patients with an eventual diagnosis of appendicitis or NSAP referred from either the Emergency Department or Primary Care.

This study established that patients referred with RIF pain to the ASU are seen in a timely manner. They have a median time taken from admission to the ASU; to clerking of 1 hour, to senior review of 2.5 hours and to documented definitive diagnosis of 16.75 hours. In patients who were taken to theatre (either for any pathology or specifically for suspected appendicitis) the median time from admission was 19 hours. The median total length of stay was 2 days. There is little data in the literature to compare this to. The only study looking at timings of this cohort of patients is McCartan's work from Ireland. They looked at time spent by patient's in the emergency department, time from surgical assessment until the decision to operate and the time to theatre after the decision was made to operate. Their median time from for this whole process was 16.6 hours but the time from surgical assessment until theatre was 13.4 hours. They identify that the shared specialty emergency operating theatre contributes significantly to the in-hospital delay of getting these patients to theatre. Our institution has similar hurdles. However, they also established that "delay in accessing the operating theatre was not associated with perforated appendicitis or post-operative morbidity".

The time from admission to diagnosis was significantly shorter for patients with a diagnosis of appendicitis compared to those with a diagnosis of NSAP. This is likely to be because definitive diagnosis in patients with appendicitis came at the time of imaging report or time of operation compared to patients with NSAP whose diagnosis was often timed at the final senior review before their discharge. However, it is reassuring that patients with appendicitis were being diagnosed in a timely manner and it is appropriate that those diagnoses are made quicker than the diagnosis of exclusion that is NSAP. When comparing the subgroup of patients who were taken to theatre with a suspicion of appendicitis, those patients who did go on to have appendicitis confirmed were taken to theatre in a significantly shorter time than those whose eventual diagnosis was not appendicitis. These data are likely to be influenced by the patients in whom there was a low suspicion of appendicitis and so had imaging, which delayed their time to theatre or where a diagnostic laparoscopy was carried out in patients with ongoing pain but

where all other diagnoses had been ruled out. Reassuringly however, NSAP was clearly actively diagnosed as the total length of stay of patients with a diagnosis of NSAP was significantly shorter than those with a diagnosis of appendicitis.

43% of all patients in this study were taken to theatre for suspected appendicitis. The negative appendicectomy rate (NAR) was 23.5%. There are however several controversies surrounding the use of NAR as a quality marker that are discussed in Chapter 10.3. The ever-increasing use of laparoscopy as the primary operative approach to RIF pain means an operation can be used as a diagnostic tool as well as treatment. Just over 5% of the patients in this study who went to theatre had a diagnostic laparoscopy only. Shelton noted, when comparing the two operative approaches, that laparoscopic appendicectomy is associated with a higher rate of normal appendicectomies and less advanced appendicitis which further strengthens the view that surgeons have a lower threshold to take patients to theatre with the laparoscopic approach and are using it as both a diagnostic and therapeutic procedure (9).

This prospective cohort study has added to the minimal existing literature looking at patients presenting with RIF pain. It confirms that the majority of patients do not have appendicitis. A large proportion of patients are discharged with a diagnosis of NSAP. Patients with an eventual definitive diagnosis of appendicitis, go to theatre significantly quicker than those that don't. Patients with appendicitis have a significantly quicker time to diagnosis and a significantly longer length of stay than those with NSAP. Male patients with RIF pain are significantly more likely to be taken to theatre for suspected appendicitis and have appendicitis on histology. The negative appendicectomy rate was not low compared to other studies in the literature but this no longer represents an appropriate outcome measure as surgeons have a lower threshold for taking patients to theatre with the laparoscopic approach.

.

Chapter 6 The role of imaging in the diagnostic pathway of patients presenting with right iliac fossa pain

6.1 Introduction

Both ultrasound (USS) and computerised tomography (CT) scans are playing an increasing role in the right iliac fossa (RIF) pain diagnostic pathway in surgical departments across the UK. Both have continued to improve in accuracy and accessibility. Their routine use has been widely adopted as an adjunct to clinical diagnosis in the assessment of RIF pain (58). The use of magnetic resonance imaging (MRI) is increasing (59–61) but its limited availability and the time constraints of completing a scan compared to USS or CT mean its use is not widespread (62).

The literature reports wide ranging sensitivity and specificities of both USS and CT (64–69) and each has its own considerations and limitations. There is large inter-user variability of ultrasound and variable quality of imaging equipment available in different centres and different countries. There are radiation and contrast issues to be considered with CT.

The aim of this part of the study was to identify the use of imaging in our unit, the accuracy of the imaging and the effect it has on the diagnostic pathway of patients presenting with RIF pain.

6.2 Methods

Ultrasound scans were performed by Sonographers, Radiology Consultants and Specialist Registrars. The ultrasound scanners in use were GE Logiq S8 and E9. The CT scanners in use were Siemens sensation 64 and GE Discovery 750 HD.

Patients who had imaging were identified via the hospital PACS system and Consultant Radiologist reports reviewed. Any queries were discussed with a Gastrointestinal specialist Consultant radiologist. Reports were then correlated with subsequent definitive diagnoses and positive and negative predictive values of USS and CT scans calculated for the most common diagnoses. USS scans were classified as nothing abnormal described (NAD) even if the reporter stated that the appendix could not be visualised, if there was no other pathology.

6.3 Results

377 patients (62.3%) had imaging as part of the diagnostic pathway.

Ultrasound abdo/pelvis and CT abdo/pelvis scans were the most common imaging modalities, one or other being used in 61.2% of all patients referred with RIF pain.

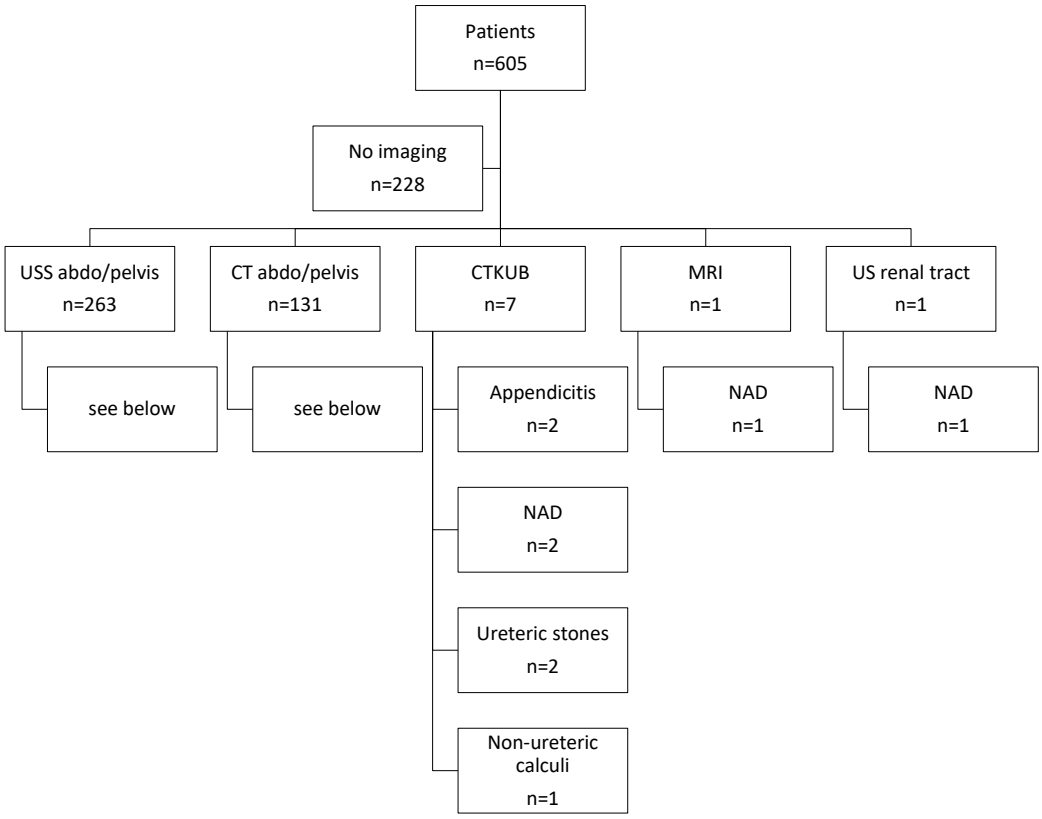


Figure 17 Report findings of patients having imaging

Figure 17 shows the report findings of patients who had imaging performed. 263 patients (43.5%) had an USS. 131 patients (21.7%) had a CT abdo/pelvis. 7 patients (1.16%) had a CTKUB. 1 MRI and 1 US of the renal tract were performed. 24 patients had both an US and a CT. One of the patients who had an US proceeded to have a CTKUB. Another of the patients who had an USS proceeded to have an MRI. 228 patients (37.7%) had no imaging during their diagnostic pathway.

Table 12 USS and CT scan requested stratified by age of patient

Age	USS	CT	p value
≤40 >40	219 44	31 100	*<0.0001***

USS were requested in significantly more patients under the age of 40 than CT scans (see Table 12).

Of the seven patients that had a CTKUB, appendicitis was reported in 2 cases, ureteric stones in 2 cases and no cause for the pain seen in 3 cases. Both the MRI and the US of the renal tract showed no pathology.

6.3.1.1 USS

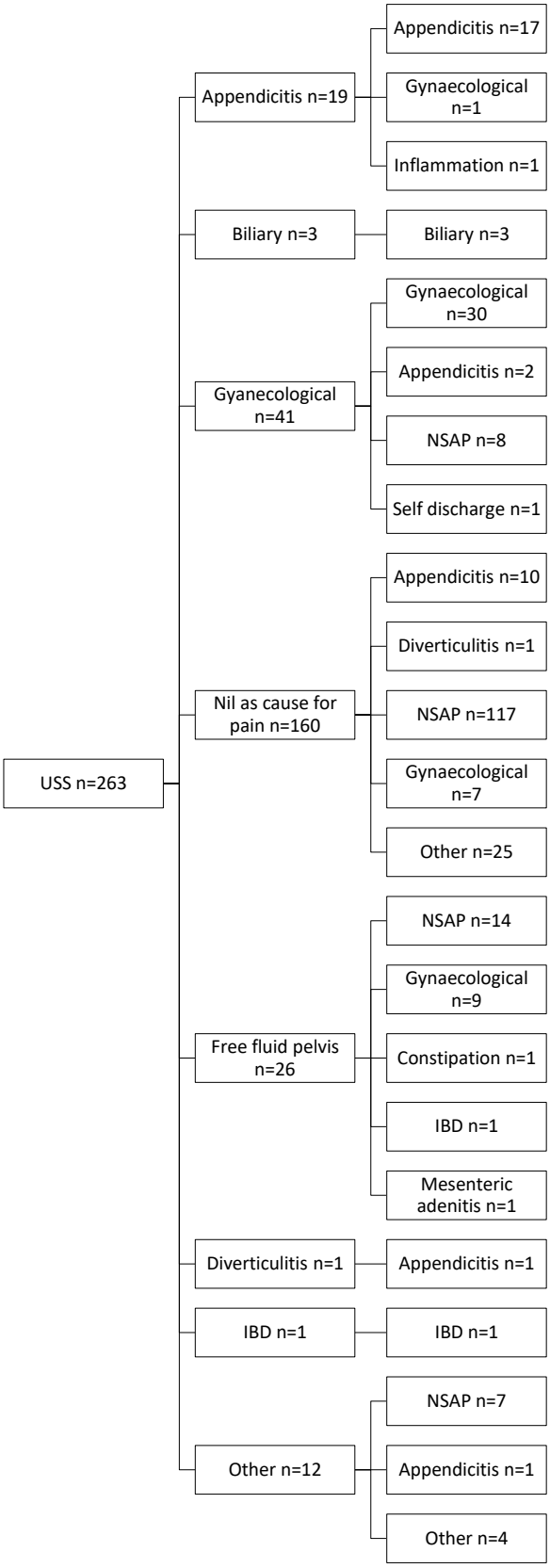


Figure 18 USS findings and correlating definitive diagnoses

Figure 18 correlates the ultrasound findings to definitive diagnoses. 19 (7.22%) of the USS performed showed appendicitis. 17 of these patients went on to have a definitive diagnosis of appendicitis. This gives USS a positive predictive value (PPV) for appendicitis of 0.89. Appendicitis was the definitive diagnosis in 14 cases where the patient's USS did not identify appendicitis. This gives USS a negative predictive value (NPV) for appendicitis of 0.94.

In three (1.14%) cases an USS showed biliary pathology and in all these patients the definitive diagnosis was biliary. No other cases of biliary pathology were found in patients who had an ultrasound. Therefore, both the PPV and NPV of USS for biliary pathology is 1.0.

41 (15.6%) of the USS performed showed gynaecological pathology. 30 of these patients went on to have a definitive diagnosis of gynaecological pathology. This gives USS a PPV of 0.73. Gynaecological pathology was the definitive diagnosis in 17 cases where the patient's USS did not identify gynaecological pathology. This gives USS an NPV of 0.92.

160 (60.8%) of the USS performed identified no cause for the RIF pain. This was the most common finding on USS. 117 of these patients went on to have a definitive diagnosis of NSAP. One of the definitive diagnoses of gynaecological pathology was mid cycle pain. Of the 25 'other' definitive diagnoses, 16 were pathologies that would not be expected to be seen on abdo/pelvis USS (constipation, enterobius infection, gastroenteritis, musculoskeletal pain, sexually transmitted infection, tonsillitis, urinary tract infection and viral infection).

26 of the USS performed showed free fluid, one showed diverticulitis, one showed IBD and 12 showed other pathologies.

6.3.1.1.1 Predictive values for USS (see Table 13)

Table 13 Positive and negative predictive values with USS

Pathology	**PPV**	**NPV**
Appendicitis	0.89	0.94
Gynaecological	0.73	0.92
Biliary	1.0	1.0

6.3.1.2 CTAP

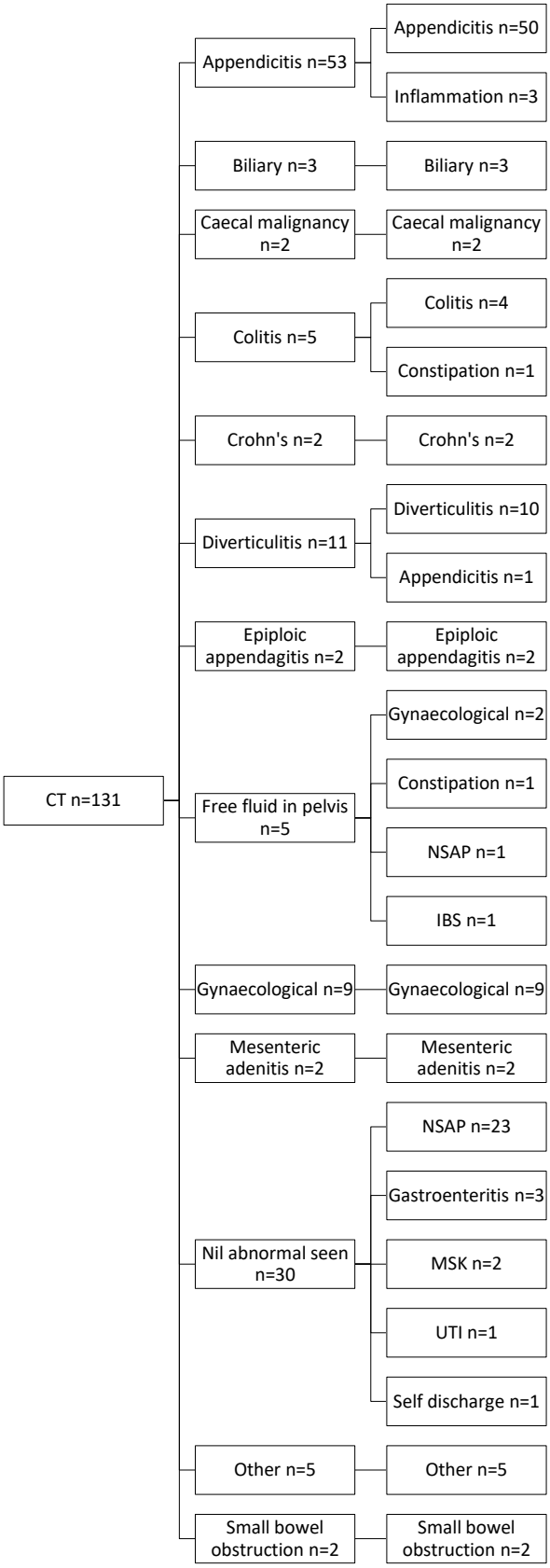


Figure 19 CT findings and correlating definitive diagnoses

Figure 19 correlates the CT findings to definitive diagnoses. 53 (40.5%) of the CTs performed showed appendicitis. 50 of these patients went on to have a definitive diagnosis of appendicitis. Appendicitis was the most common finding on CT scan. CT has a positive predictive value (PPV) for appendicitis of 0.94. Appendicitis was the definitive diagnosis in one case where the patient's CT did not identify appendicitis. This gives CT a negative predictive value (NPV) for appendicitis of 0.99.

In three (2.29%) cases the CT showed biliary pathology and in all these patients the definitive diagnosis was biliary. No other cases of biliary pathology were found in patients who had a CT. Therefore, both the PPV and NPV of CT for biliary pathology is 1.0.

11 (8.40%) of the CTs performed showed diverticulitis. 10 of these patients went on to have a definitive diagnosis of diverticulitis. This gives CT a PPV for diverticulitis of 0.91. No other cases of diverticulitis were found in patients who had a CT. This gives CT an NPV for diverticulitis of 1.0.

30 (22.9%) of the CTs performed identified no cause for the RIF pain. 23 of these patients went on to have a definitive diagnosis of NSAP. The remaining seven patients had definitive diagnoses that would not be seen on a CT scan (gastroenteritis, musculoskeletal pain, urinary tract infection and one self-discharge patient).

Nine (6.87%) of the CTs performed showed gynaecological pathology. All these patients went on to have a definitive diagnosis of gynaecological pathology and therefore gives CT a PPV for appendicitis of 1.0. gynaecological pathology was the definitive diagnosis in two cases where the patient's CT did not identify that. This gives CT a negative predictive value (NPV) for gynaecological pathology of 0.98.

Five (3.82%) of the CTs showed colitis. 4 of these patients went on to have definitive diagnoses of colitis. This gives CT a PPV for colitis of 0.8. No other cases of colitis were found in patients who had a CT. This gives CT an NPV for colitis of 1.0.

Two of the CTs showed caecal malignancies, two showed Crohn's disease, two showed epiploic appendagitis, two showed mesenteric adenitis and two showed small bowel obstruction. In all those cases the CT report was correct when compared to the definitive diagnosis.

6.3.1.2.1 Predictive values for CT (see Table 14)

Table 14 Positive and negative predictive values with CT

Pathology	**PPV**	**NPV**
Appendicitis	0.94	0.99
Biliary	1.0	1.0
Colitis	0.8	1.0
Diverticulitis	0.91	1.0
Gynaecological pathology	1.0	0.98

6.3.1.3 No imaging

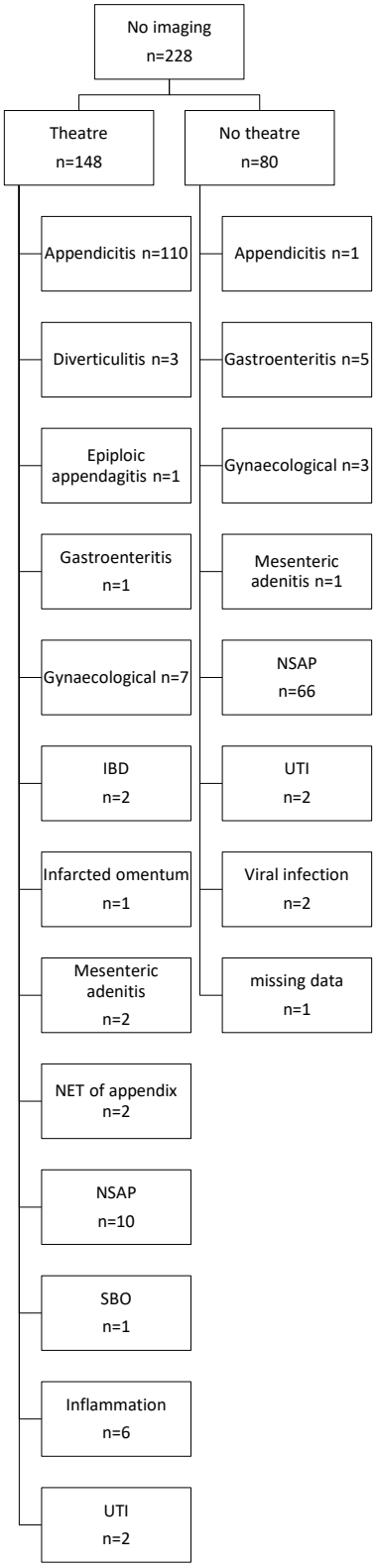


Figure 20 Patients with no imaging stratified by theatre or no theatre

228 patients had no imaging (Figure 20). These can be split into two categories; those that had no imaging because the decision was made to go straight to theatre and those that had neither imaging nor an operation.

148 patients were taken to theatre without having had any imaging (24.5% of the total cohort of the study). 110 patients had appendicitis (74.3%). Two patients had neuroendocrine tumours of the appendix. The negative appendicectomy rate was 24.3%.

80 patients had no imaging and were not taken to theatre (13.2% of the total cohort).

One patient was initially discharged having had no imaging and then represented and required a laparotomy for a perforated appendicitis.

6.3.2 **Does imaging delay the time to theatre?**

Table 15 Time to theatre for patients with appendicitis

Imaging type	**Number of patients**	**Median time from admission to theatre**
USS only	61	25.42 (18.13-29.87)
CT only	43	18.4 (12.3-27.48)
Both	3	77.5 (53-97)
CTKUB	2	17.6 (4.2-31)
No imaging	**148**	**13.75 (7.475-22.13)**
Any imaging	**109**	**21 (13.13-28.92)**

Imaging does cause a significantly delay to theatre ($p<0.0001$) for patients with an eventual definitive diagnosis of appendicitis compared to patients who do not have any imaging (see Table 15).

6.3.3 **Is there a decrease in the negative appendicectomy rate (NAR) with imaging?**

Table 16 Comparison of patients going to theatre after imaging or no imaging

Patients going to theatre for suspected appendicitis	**Imaging**	**No imaging**	**p value**
Number of patients	109	148	
Diagnostic lap only	6	9	>0.9999
Negative appendicectomy rate	36.2%	17.6%	0.0017**

Patients going to theatre for suspected appendicitis with no imaging have a significantly lower negative appendicectomy rate (17.6%) that those who go to theatre after imaging (36.2%). There is no difference in the rate of diagnostic laparoscopy (see Table 16).

6.3.4 Is the accuracy of imaging operator dependent?

One of the well stated disadvantages of USS is its operator dependent variability. Three categories of clinicians were performing USS at our institution during the study period; Consultant Radiologists, Registrar Radiologists and Sonographers. The individual accuracy of each group was looked at. Where a clinician was being supervised, the most senior clinician in the room was documented. The USS diagnosis (as taken from the PACS electronic reporting system) was compared to the definitive diagnosis as already described. Findings were taken to show correlation if

- The diagnoses agreed or
- The definitive diagnosis would not be expected to be seen on ultrasound
    - for example, USS diagnosis: NAD/no cause for pain seen Definitive diagnosis of a viral infection (which you wouldn't expect to have any abdominal findings on USS) or
- The USS diagnosis was not definitive but was appropriate and led to further investigation
    - for example, USS finding: RIF Inflammation Definitive diagnosis: right sided colitis.

6.3.4.1 Results

Clinician grade	**Number of scans**	**Number that correlate**	**Percentage**
Consultant Radiologist	53	45	**85.0**
Radiology StR	27	24	**88.9**
Sonographer	183	170	**92.9**

Figure 21 USS correlation with definitive diagnosis by performer

The highest proportion of US scans was done by the sonographers. Scans performed by them showed the highest level of correlation to the definitive diagnosis (see Figure 21).

6.4 Discussion

Radiological imaging was widely utilised for patients in this study. 62.3% of all patients referred with RIF pain had some form of imaging. Overall USS was the most widely utilised imaging at 43.5%. USS was the first line radiological investigation in patients under 40 years of age and CT was the first line modality in patients over the age of 40 years. This is in line with current literature and the likelihood of underlying diagnoses balanced against concerns about radiation exposure (65,69,85,134).

Positive predictive values and negative predictive values vary widely in the literature. This cohort of imaged patients is large compared to other studies. PPV of ultrasound for appendicitis is at a similar level to other studies but the NPV shows it outperforming other studies in terms of its accuracy.

The PPV of CT for appendicitis is similar but slightly under the level of the other studies whereas the NPV is extremely similar to the other studies, apart from Flum which seems to be an outlier (see Table 17).

Table 17 PPV and NPV of USS and CT scans

Study	Number of patients in study (having imaging)	PPV	NPV
Flum 2005(58) USS CT	549 (estimated sample)	 0.94 0.97	 0.65 0.64
Horton 2000 (68) USS CT	89	 0.96 1.0	 0.56 0.92
Poortman 2009 (69) USS CT	151	 0.90 1.0	 0.71 1.0
Wise 2001 (135) USS CT	100	 0.42 0.71	 0.81 0.91
Pearson 2018 *USS* *CT*	*377*	 *0.89* *0.94*	 *0.94* *0.99*

Imaging tends to be used in cases of equivocal clinical diagnosis in our unit. Because of the high rates of gynaecological and non-specific abdominal pathology in young women (see Figure 12), USS is often routinely used in these patients. Older patients are more at risk of malignancy and other pathology such as diverticulitis and should have a CT (31,63,136).

Imaging does affect, not only the diagnostic pathway of patients but also the ongoing management pathway. The use of imaging causes significant delays in patients going to theatre. In this study there was a statistically significant difference ($p<0.0001$) of over 7 hours between patients with an eventual definitive diagnosis of appendicitis going to theatre who had had imaging compared to those who had not. McCarten et al (12) who described the same findings also showed that there was no difference between the groups in terms of perforation or post-operative morbidity. Their argument is that the patients that go straight to theatre without imaging are likely to have more severe and therefore more clinically obvious appendicitis compared to the imaging group which are likely to have less severe appendicitis and therefore tolerate a delay to theatre more readily. In our study, of the 13 patients that had complications following an operation for acute appendicitis, six had had imaging.

This study shows that imaging does not decrease the negative appendicectomy rate (NAR), a finding in line with other studies (12,58). In fact, patients who had imaging had a significantly higher negative appendicectomy rate at 36.2% than those who had not, at 17.6% ($p=0.0017$). There are several factors that affect negative appendicectomy rate that will be further discussed in Chapter 10. NAR does not take account of the intra-operative complex decision making that occurs during a diagnostic laparoscopy for RIF pain. The advent of laparoscopic appendicectomy means that not all normal looking appendices are removed compared to when open procedures were routine. Faced with a macroscopically normal appendix the operating surgeon can decide to leave it or remove it. This might be influenced by the surgeon's or the surgical unit's personal preference or patient factors such as repeated attendances with RIF pain. None of these considerations are reflected in the NAR.

USS report correlation to definitive diagnosis was most accurate when the US was done by sonographers in these data. It is difficult to draw definite conclusions from this as the numbers involved are small. Sonographers performed 70% of all USS done within the study period. At this time two advanced abdominal sonographers with an interest in right side abdominal scanning were employed by the trust. This is likely to have contributed to both the high number of scans that were performed by sonographers and their level of accuracy. Further work should continue to look at the clinician performing the US scan as it is such an operator dependent imaging modality.

This study shows that in our population selective USS and CT are routinely used in the diagnostic pathway of patients referred with RIF pain. They have good positive and negative predictive values for appendicitis with CT slightly outperforming USS. Imaging however does delay time taken from admission to theatre and does not decrease negative appendicectomy rate.

Chapter 7 Validation of scoring systems

7.1 Introduction

Scoring systems have been used as a risk stratification tool for diagnosis of appendicitis but lack widespread uptake. Two scores, the Alvarado Score and the Appendicitis Inflammatory Response (AIR) Score have been recorded for the patients in this study.

Whilst the Alvarado score has historically been the most successful it does not have broad uptake among surgeons in day to day practice, due to various weaknesses (93). The Alvarado score performs poorly in women of child bearing age and in children (94). The score was written based on a retrospective review of patients who had been operated on for a possible diagnosis of appendicitis. This is not the same cohort of patients they are suggesting the score be applied to. This may lead to scoring weight bias (94).

Andersson et al have devised a new tool, the AIR Score (93), which in their Swedish population outperformed the Alvarado score and selected the indeterminate group of patients which would benefit from further investigation and imaging. The score has been validated by de Castro in a Dutch population and by Scott in a UK population. In contrast to the Alvarado score it incorporates the CRP value and was validated prospectively on all patients with suspected appendicitis (95).

Literature to date suggests that the Alvarado score is best used as a rule out score at a level ≤4 and the AIR score as a rule in at a level ≥9 (93,95–97).

This study aims to compare the accuracy of both scores in our large UK cohort to see if either could reliably be used in a local RIF pain diagnostic pathway.

7.2 Methods

Alvarado and AIR scores were calculated for patients in the study over the three data collection phases. Scores were calculated by prospectively collecting the relevant demographic, clinical and laboratory data at the time of presentation. Any queries were checked in the notes or with the clerking doctor. The treating surgical team was blinded to the score.

7.3 Results

There were 605 patients in the overall study. Scores were calculated for 595 of these patients .It was not possible to calculate scores for 10 patients due to incomplete data.

7.3.1 **Alvarado Score**

The Alvarado scale splits patients into low, intermediate and high-risk of appendicitis groups based on a score of 0-4, 5-6 and 7-10 respectively. Table 18 shows the numbers in each Alvarado score group in this study. 267 patients (93.7%) of the low-risk group did not have appendicitis. Only 110 patients (68.3%) of patients in the high-risk group had appendicitis.

Table 18 Alvarado score data

Alvarado Score	**Number of patients**	**Patients with appendicitis**	**% group with appendicitis**
0-4	285	18	6.31
5-6	149	58	38.9
7-10	161	110	68.3
missing	10	1	n/a

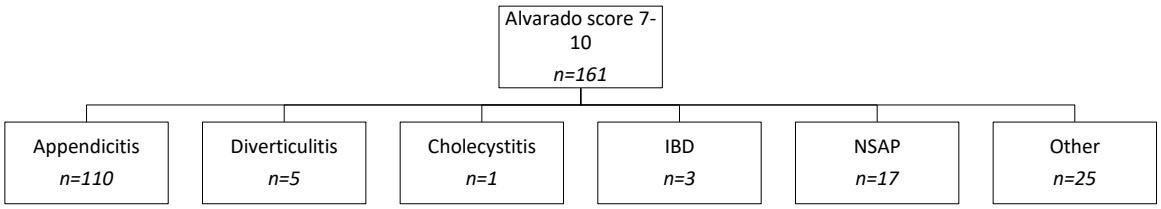


Figure 22 Definitive diagnoses of patients in the Alvarado high-risk group

Figure 22 shows the definitive diagnoses of all the patients in the high-risk group. In addition to the 110 patients with a definitive diagnosis of appendicitis in the high-risk group, there were five patients with diverticulitis, one with cholecystitis and three with inflammatory bowel disease. All these patients required further investigation and treatment of their infective or inflammatory pathologies. 17 patients (10.6%) had a subsequent definitive diagnosis of NSAP.

7.3.2 **AIR Score**

The AIR score splits patients into low, intermediate and high-risk of appendicitis groups based on a score of 0-4, 5-8 and 9-12 respectively. Table 19 shows the numbers in each AIR score group in this study. 328 patients (89.9%) of the low-risk group did not have appendicitis. 32 patients (88.9%) of patients in the high-risk group had appendicitis.

Table 19 AIR score data

AIR Score	**Number in group**	**Patients with appendicitis**	**% group with appendicitis**
0-4	365	37	10.1
5-8	194	120	61.8
9-12	36	32	88.9
missing	10	1	n/a

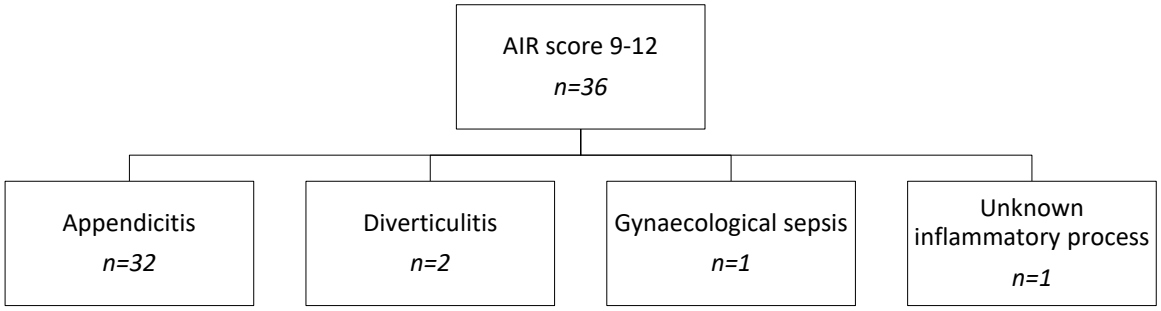


Figure 23 Definitive diagnoses of patients with AIR score 9-12

Figure 23 shows the definitive diagnoses of all the patients in the high-risk group. In addition to the 32 patients with a definitive diagnosis of appendicitis in the high-risk group, there were two patients with diverticulitis, one with gynaecological sepsis and 1 an unknown inflammatory process with WCC 16, CRP 205 and a CT showing free fluid. Therefore, all patients with a score ≥9 needed treatment with antibiotics and/or theatre.

7.3.2.1 Predictive values for scoring systems for appendicitis

The original Alvarado paper further split the 'high risk of appendicitis' group into 'high risk' with scores 7-8 and 'very high risk' with scores 9-10. Comparisons in the literature of the PPV and NPV of the scoring systems are made with the 'very high risk' scoring category (see Table 20).

Table 20 Comparison of PPV and NPV for scoring systems

	PPV	**NPV**
Alvarado Score		
Score of ≥5	0.54	0.94
Score of ≥9	0.90	0.79
AIR Score		
Score of ≥5	0.66	0.90
Score of ≥9	0.89	0.72

In this study the Alvarado score had a PPV for appendicitis with a score more than or equal to 9 of 0.90 compared to the AIR score which had a PPV of 0.89. The Alvarado score has an NPV for appendicitis with a score less than 5 of 0.94 compared to the AIR score which has an NPV of 0.90.

7.4 Discussion

In contrast to other studies of similar or smaller size, these data show the AIR score does not outperform the Alvarado score in discriminating for and against a diagnosis of appendicitis when comparing PPV and NPV. This is the largest evaluation of the AIR score in a UK population (97).

7.4.1 **Comparison to literature**

7.4.1.1 Alvarado Score

Table 21 Comparison of studies validating the Alvarado Score

Paper	**Number of patients in study**	**PPV for appendicitis**	**NPV for appendicitis**
Andersson 2008 Score ≥5 Score ≥9	545	 0.56 0.91	 0.98 0.73
De Castro 2012 Score ≥5 Score ≥9	941	 0.53 0.77	 0.90 0.70
Tan 2013 Score ≥5 Score ≥9	358	 0.62 1.0	 0.79 0.52
Pearson 2018 *Score ≥5* *Score ≥9*	*595*	 *0.54* *0.90*	 *0.94* *0.79*

Table 21 shows the Alvarado score performing in a similar manner to other large studies. Its greatest strength is as a rule out (NPV with a low score) tool.

7.4.1.2 AIR Score

Table 22 Comparison of studies validating the AIR score

Paper	**Number of patients in study**	**PPV for appendicitis**	**NPV for appendicitis**
Andersson 2008 Score ≥5	545	 0.64	 0.97

Score ≥9		0.97	0.76
De Castro 2012 Score ≥5 Score ≥9	941	 0.79 1.00	 0.95 0.66
Scott 2015 Score ≥5 Score ≥9	464	 0.49 0.97	 0.94 0.76
Pearson 2018 *Score ≥5* *Score ≥9*	*595*	 *0.66* *0.89*	 *0.90* *0.72*

Table 22 shows the AIR score performing less effectively as both a rule in (PPV with high score) and a rule out (NPV with low score) tool for appendicitis than in previous literature.

De Castro et al (95) give a good rationale for the use of scoring systems. They emphasise their role in suggesting the probability of the diagnosis of appendicitis rather than aiming to categorically establish it as the primary diagnosis. They remind us that it can be used to select which patients should follow the different pathways of immediate surgery, undergo imaging or who don't require intervention. This tallies with the results from this study where interrogation of the 'high risk' groups for both scores show pathology requiring further investigation and management even if not appendicitis. This is particularly the case with the AIR score where 100% of the patients in the 'high risk' group required an operation or antibiotics. This was also found by Scott et al (97) who suggested that a high AIR score could be used to indicate patients with a high risk of morbidity who should be reviewed early by a senior surgeon. They also suggest an interesting point relevant to this overall study, that the AIR score, acting as an adjunct to clinical judgement is particularly useful given that most of these patients are being assessed initially by relatively inexperienced junior clinicians, who will not make 'consistently accurate diagnoses'. This usefulness can be expanded to apply to any risk stratification tool or diagnostic adjunct such as a CDST.

7.4.2 **Conclusions**

In this large cohort study, the AIR score does not outperform the Alvarado score for the risk stratification of appendicitis diagnosis as previous studies have suggested.

Chapter 8 Effects of the clinical decision support tool

8.1 Introduction

Accuracy in the diagnosis of patients presenting with right iliac fossa (RIF) pain can be improved (137). Evidence from the literature (see Chapter 1), from the local data (See Chapter 3) and from the clinician survey (see Chapter 5) supports the need for a clinical decision support tool (CDST) in the diagnostic pathway of RIF pain. There is a variety of investigative options including the use and timing of radiology and diagnostic laparoscopy. There can be delays between clerking of patients and a senior clinician review, and that can cause a delay to the initiation of investigation and management if the clinician who is clerking is not acting as a decision maker.

The publication of the Royal College of Surgeons commissioning guidelines (8) showed an appetite for standardizing serves in emergency general surgery. What is considered as best practice is constantly changing, as new evidence emerges, and we need to make our actions evidence based. The local clinician survey and discussions showed enthusiasm for having an informative tool to aid this process.

The goal of the tool was to increase the effectiveness of the clerking doctor with reference to decision making. The three parts of the proforma aimed to achieve this in the following ways:

The educational content was developed with the aim of helping the clinician think about the history and examination findings and how they would guide a likely differential diagnosis. This content was freely available in the literature and educational sources. Talking to junior clinicians, they often felt seniors make decisions without explaining their rationale or which subtlety of the history or examination made them come to their diagnostic conclusions. The educational content did not just focus on appendicitis but the other major differentials for RIF pain as well.

The proforma itself did not deviate radically from the standard history and examination format but prompted the clerking doctor to focus on not just a diagnosis but what pathway this patient needed to follow based on the information gathered so far. The CDST could then be used based on this decision by the clerking doctor. Using the pre-implementation questionnaire, the results of the pilot study and the literature search, the tool focused on the five options for patients: requirements for discharge, for observation and review, for imaging, for theatre or transfer to another intra or inter specialty pathway.

8.2 Methods

302 patients were referred with RIF pain during the implementation stage of the study from January to June 2015. During this time, it was envisioned that all patients in the Acute Surgical Unit would be clerked using the new Right Iliac Fossa Pain Proforma (for details of the proforma and CDST see Chapter 6). The aim was to start patients down the most appropriate imaging and management pathways.

8.3 Results

8.3.1 Usage of the RIF pain proforma

The intention of the study was that the proforma would be used every time a patient with RIF pain was clerked. However, this goal was not achieved (see Figure 24). The proforma was used on 44 occasions.

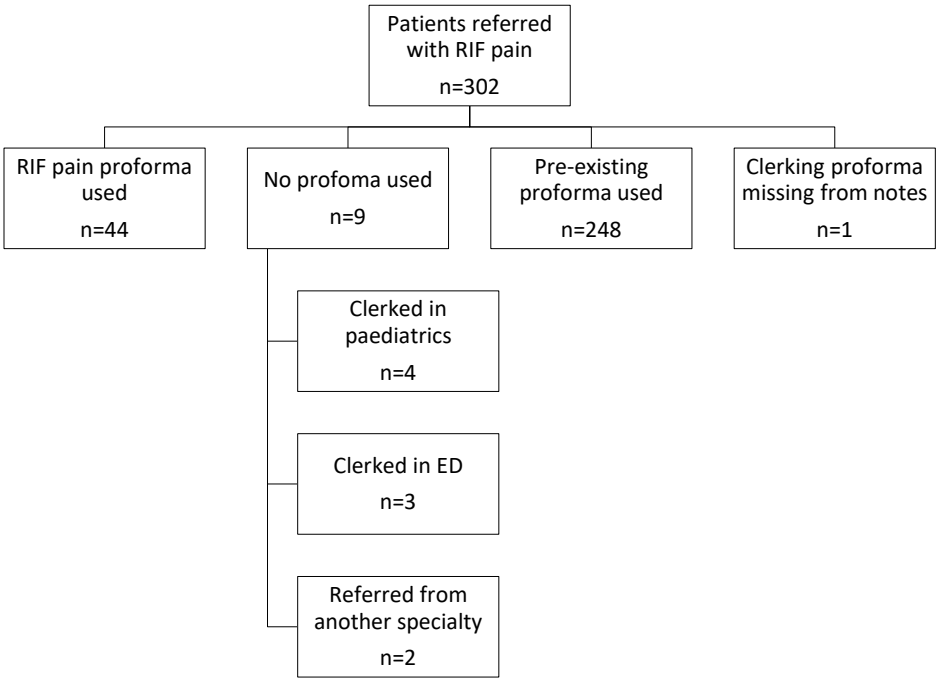


Figure 24 Consort diagram for proforma use

On four occasions the patient was clerked by the surgical team on the paediatric ward with no proforma. These were all 16-year olds who, in our institution, are referred to the adult surgical team but have the option to go onto a paediatric ward remote from our acute surgical unit. On three occasions the patient was clerked by the surgical team in the emergency department with no proforma. On two occasions patients were referred, already clerked, from another specialty (gynaecology or urology). In 248 patients the pre-existing General Surgery clerking proforma was

used instead of the RIF pain proforma. The clerking proforma of one patient in the study was missing. Although not the original design of the study, this enabled the pre-determined outcome measures to be compared in the RIF proforma group and the original proforma group.

The baseline characteristics were the same for each group (see Table 23):

Table 23 Demographics of the two study cohorts

	Original proforma n	**%**	**RIF proforma** n	**%**	p value
Number of patients	248		44		
Age					>0.9999
<30	133	**53.6**	24	**54.5**	
≥30	116	**46.4**	20	**45.5**	
BMI					>0.9999
<25	107	**43.1**	19	**43.2**	
≥25	139	**56.0**	24	**54.5**	
missing	2	**0.81**	1	**2.27**	
Gender					0.3895
Male	82	**33.1**	18	**40.9**	
Female	164	**66.1**	26	**59.1**	
missing	2	**0.81**			
Charlson index					>0.9999
0	188	**75.8**	34	**77.3**	
≥1	60	**24.2**	10	**22.7**	

Median age for both groups was 27 years. Median BMI for both groups was 25. Median Charlson index score was 0 for both groups.

8.3.2 Outcome measures

The primary endpoint of this study was the proportion of senior review plans that agreed with the junior clinician initial plan, indicating that the plan of the junior clinician was correct.

Secondary endpoints were time taken from admission to the ASU to the definitive diagnosis and to theatre and total length of stay.

Several questions were used to assess the impact of the new proforma.

- Was the proforma used?
- If so, was the guidance suggested in the educational content and the CDST followed?

This was judged by looking at the history and examination findings documented and running them through the algorithms.

- Did the management plan arising from the subsequent senior review agree with the plan suggested by the clerking doctor?

8.3.3 Comparison of outcomes between the two proformas

8.3.3.1 Use of guidance on the proforma

As described in Chapter 6.2 the RIF pain proforma contained guidance in the form of the CDST that was not part of the original proforma. The management plan of the clerking doctor was compared to the plan that would be generated if the guidance was followed for clinicians using either proforma.

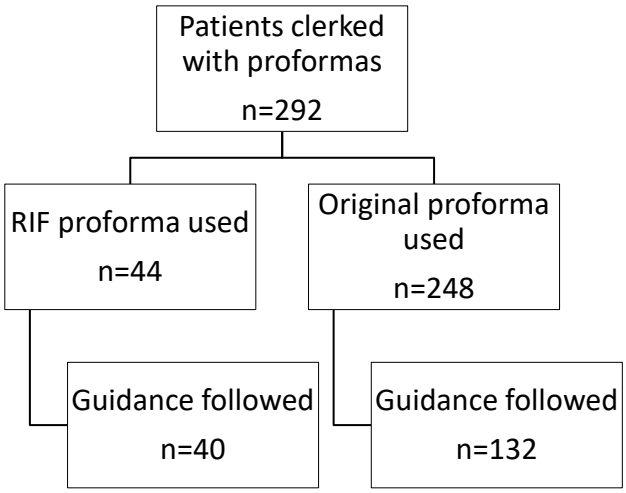


Figure 25 Comparison of proforma guidance use

Guidance was followed 90.9% of the time when the RIF proforma was used compared to 53.2% of the time when the original proforma was used (Figure 25).

In some instances, the clerking doctor was a senior clinician. These were excluded from further analysis and clerkings conducted by junior clinicians (medical student, Foundation Year 1, Nurse practitioners, Foundation Year 2, Core Surgical Trainee years 1 and 2 and Trust grade doctors) were therefore looked at separately (Figure 26).

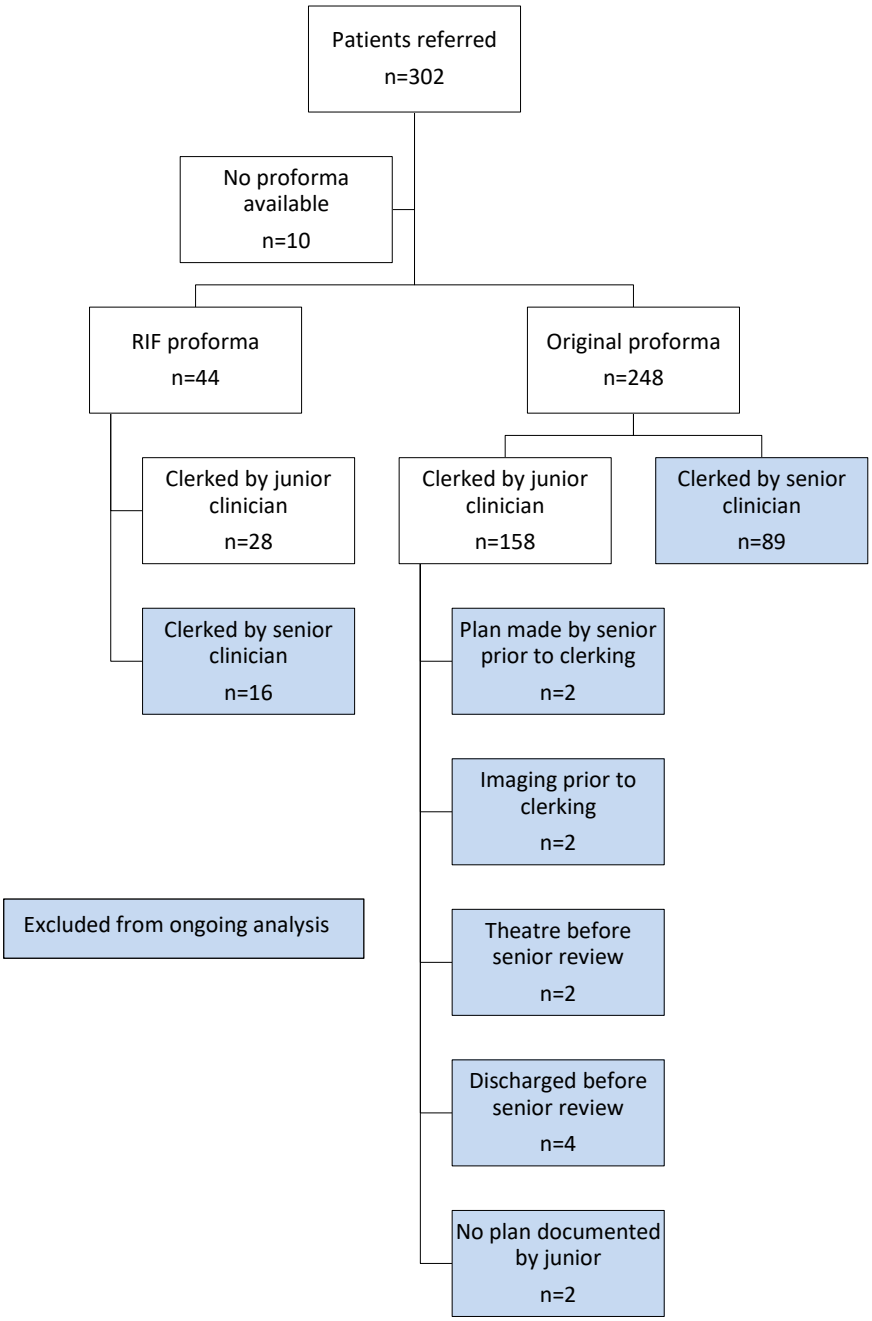


Figure 26 Method and grade of clinician conducting clerking

It was impossible to comment on the correlation of the junior and senior clinician plans in 12 patients. Two were seen by the senior clinician in ED before clerking and a plan documented. Eight patients had plans fully initiated before senior review including discharge imaging or theatre and two patients had no plan documented by the clerking doctor.

8.3.3.2 Did the senior clinician plan agree with the junior clinician clerking?

Table 24 Concurrence of junior and senior clinician plan

	Senior review didn't agree with junior plan	Senior review did agree with junior plan	*p value*
Original proforma	101	45	*<0.0001***
RIF proforma	3	25	

Use of the RIF pain proforma with CDST significantly increases the appropriateness of the plan given by the junior clerking doctor as measured by the correlation with the senior clinician review (Table 24).

8.3.3.3 Time taken from admission to: senior review, definitive diagnosis, theatre and length of stay

Secondary outcome measures of this study were whether there were any differences within the two groups in time taken from admission to senior review, to definitive diagnosis, to theatre and length of stay.

Table 25 Comparison of time taken from admission to set time points

	Original proforma	**RIF Proforma**	*p value*
Time to senior review (median in hours)	2.5	2	0.6131
Time to definitive diagnosis (median in hours)	15	14.7	0.6403
Time to theatre (median in hours)	17.725	24.75	0.9923
Length of stay (median in days)	2	2	0.5047

There was no statistical difference in the outcome measures between the two groups in any category (Table 25).

8.3.4 Imaging

One potential concern of a pathway change might be frequency of imaging and whether this changed with the introduction of the proforma and therefore this was analysed.

Table 26 Comparison of USS frequency

	Had USS	**No USS**	*p value*
Original proforma **RIF proforma**	111 22	137 22	0.6226

Table 27 Comparison of CT scan frequency

	Had CT	**No CT**	*p value*
Original proforma **RIF proforma**	51 6	197 38	0.4084

There was no statistical difference in the total number of USS (Table 26) or CT scans (Table 27) requested using the new proforma.

There was no change in the frequency of imaging requested with introduction of the new proforma. Therefore, the pathway should not incur increased radiology costs or have increased radiation concerns.

The next stage was to examine who was requesting the imaging. For this analysis again, only the patients clerked by a junior clinician were included and Table 28 and Table 29 show the proportion of imaging requested by the junior or senior clinician.

Table 28 Comparison of grade of clinician requesting USS

	USS requested by junior clinician	**USS requested by senior clinician**	*p value*
Original proforma **RIF proforma**	36 10	33 5	0.3956

Table 29 Comparison of grade of clinician requesting CT

	CT requested by junior clinician	**CT requested by senior clinician**	*p value*
Original proforma **RIF proforma**	3 3	24 2	*0.0342**

There was no difference in the proportion of USS requested by the junior clinician when the clinical decision tool was used. However, use of the clinical decision tool led to 60% of CTs being requested by the junior clerking clinician compared to only 11% when the old proforma was used. This is a statistically significant difference. This correlates to imaging being requested earlier and the patient's investigative plan being advanced at an earlier stage.

8.3.5 To theatre

Table 30 Comparison of patients taken to theatre

	Theatre for suspected appendicitis	**No theatre or not for appendicitis**	*p value*
Original proforma	100	148	0.097
RIF proforma	24	20	

There was no statistical difference in the number of patients taken to theatre for suspected appendicitis (Table 30).

Table 31 Comparison of appendices removed

	Appendix removed	Appendix not removed	*p value*
Original proforma	95	5	0.5820
RIF proforma	24	0	

There was no statistical difference in the number of appendices not removed at diagnostic laparoscopy (Table 31).

Table 32 Comparison of negative appendicectomy rates

	Appendicitis on histopathology	**Not appendicitis on histopathology**	*p value*
Original proforma	70	25	0.3156
RIF proforma	15	9	

There was no statistical difference in negative appendicectomy rates (Table 32).

8.4 Discussion

This CDST integrated into the RIF Pain proforma fulfilled Liu's requirements (125) for a successful tool design. It targeted the clerking clinician to aid them as a decision maker. It targeted decisions surrounding each individual patient as to the diagnostic pathway they should follow. It integrated a knowledge component to aid the decision making and it was placed to assist the clinician before they took the diagnostic decisions.

The senior clinician review plan agrees with the plan of the clerking junior clinician more when the RIF proforma is used. This is a statistically significant finding. We hypothesise that this represents the junior clinician making a correct plan significantly more of the time when using the RIF proforma and that it therefore makes them better decision makers. This is also supported by a

significantly higher proportion of CTs being requested by the junior clerking clinician than the senior clinician with the use of the clinical decision tool.

Use of the proforma in these data does not affect the time from admission to senior review, to definitive diagnosis, to theatre or the total length of stay in these data.

Use of the proforma does not affect the frequency of imaging, the number of patients taken to theatre, the number of appendices removed or the negative appendicectomy rate. Therefore, there should be no concerns about increased cost of the pathway or increased radiation doses to patients in these data.

All of the above conclusions must be taken in the context of the small numbers involved due to low volume usage of the proforma and hence CDST by clinicians. No definitive conclusions can be drawn. Significant work needs to be done to increase the use of the proforma by clinicians. This will allow further evaluation of the tool and increase its potential effectiveness. This is discussed further in Chapter 10.4.

There is no CDST of this nature discussed in the literature and it is therefore difficult to gauge its effectiveness or know what the best outcomes are to judge it by. The outcomes used in this study were chosen to be clinical and practical and are easily recorded. Further work should be done to validate the tool and the outcome measures used to assess it and other implementations like it.

Chapter 9 Post-implementation survey

9.1 Introduction

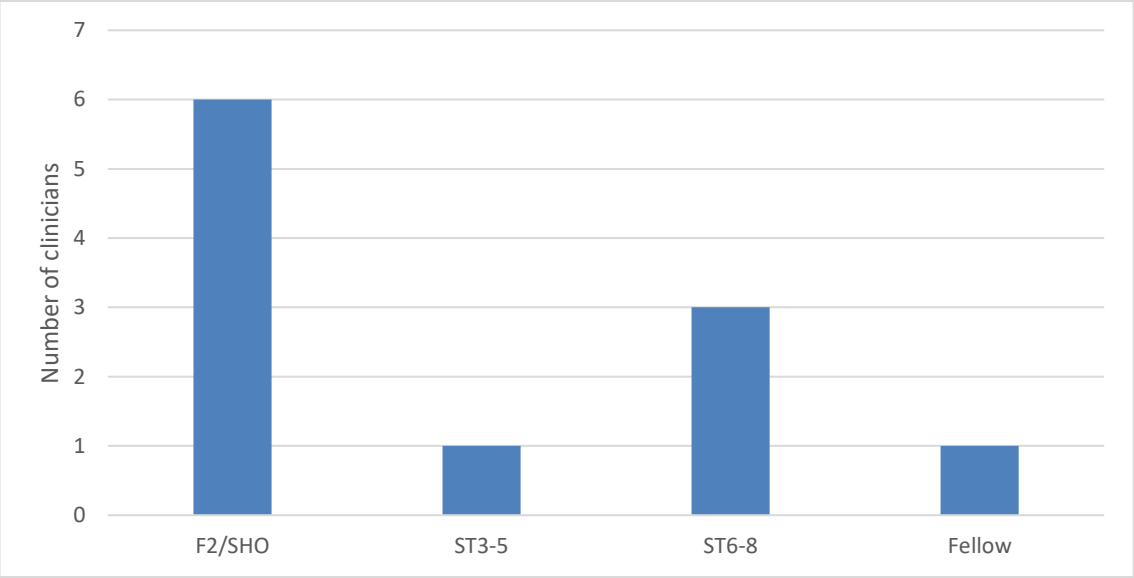
This survey was conducted after the finish of the implementation stage. Its aim was to gain the opinions of the clinicians who had been using the tool. It was an adjunct to the objective outcome measures used for assessment of the tool.

9.2 Methods

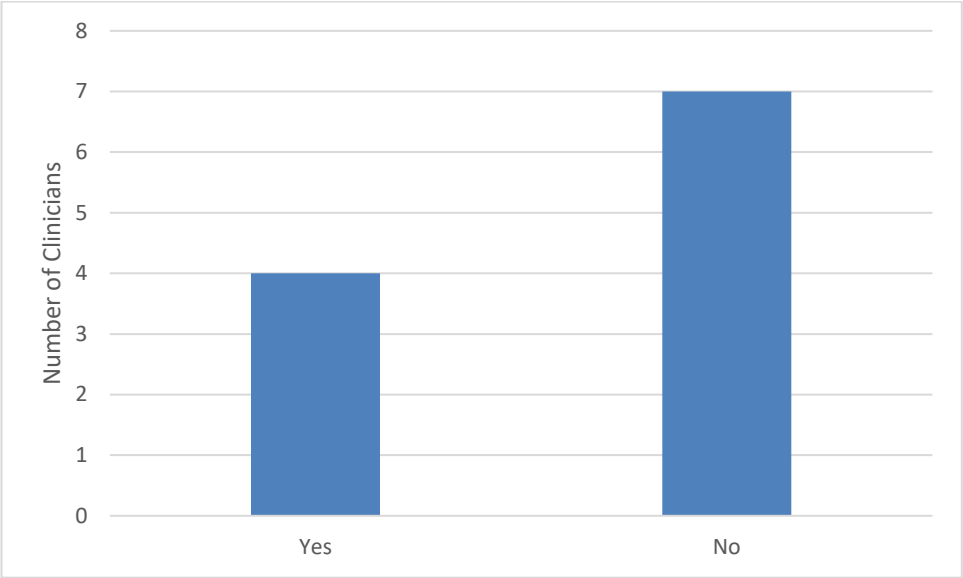
The survey was sent to 19 clinicians identified as SHOs or registrars who had been on call or on ASU over the period of the study. During this period the surgical F1s were not responsible for clerking patients. The survey was sent by email and reminders were sent at ten days.

9.3 Results

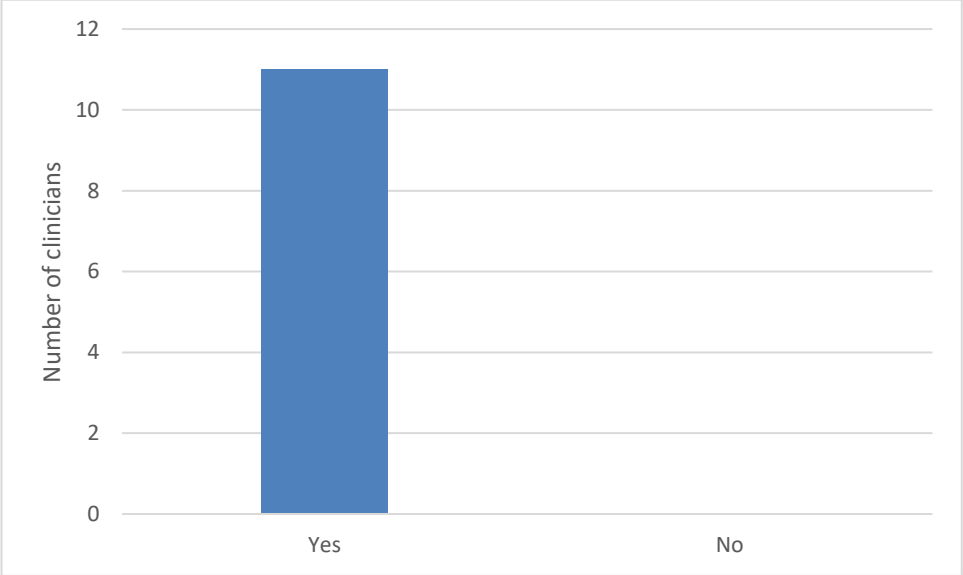
9.3.1 What grade are you?



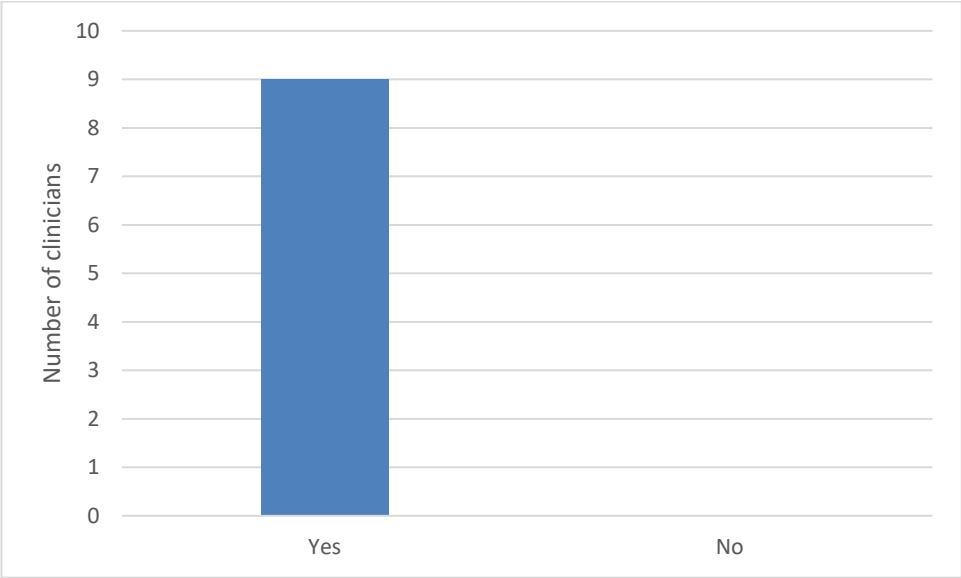
9.3.1.1 Do you currently or have you previously worked as a 'day job' on the ASU team (excluding on call)?



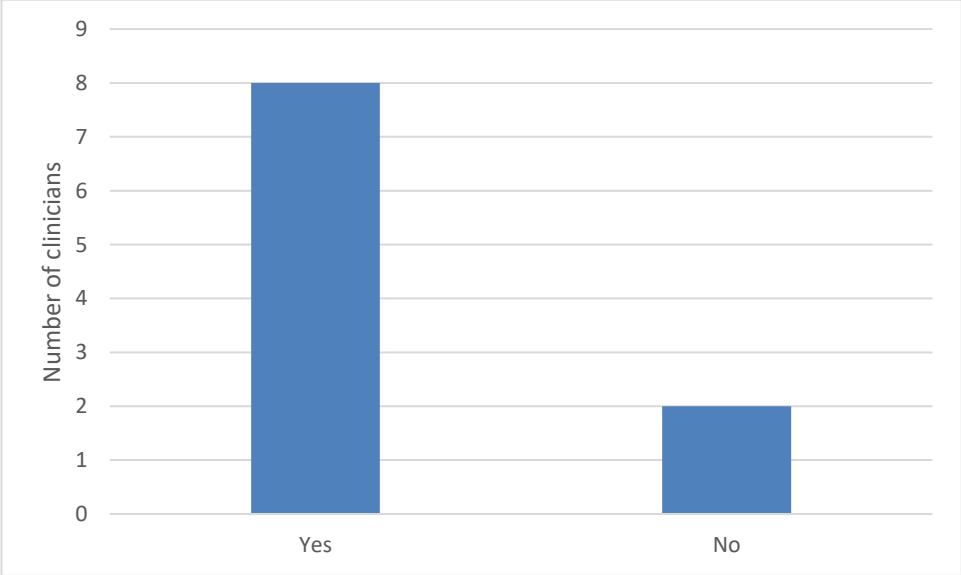
9.3.1.2 Are you or have you been part of an on-call rota that covers the Acute Surgical Unit?



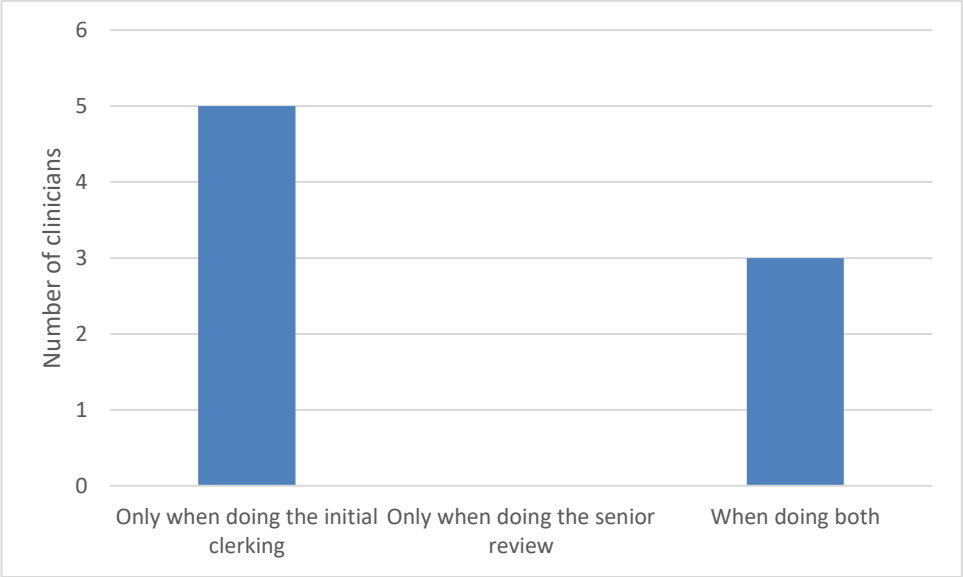
9.3.1.3 Since August 6th, 2014 have you clerked or been the senior review on any acute admission referred with right iliac fossa pain?



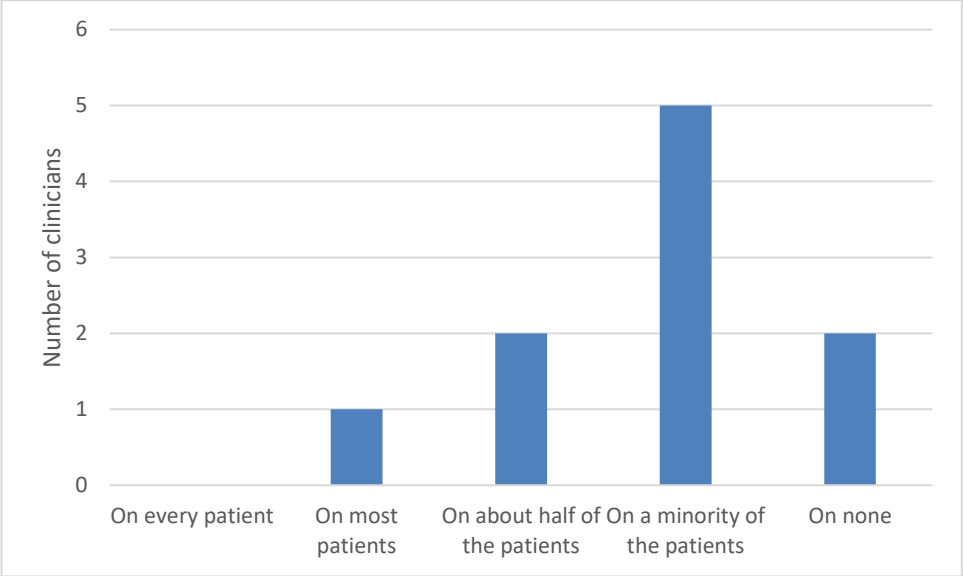
9.3.1.4 In any of those cases did you use or look at the right iliac fossa decision support tool?



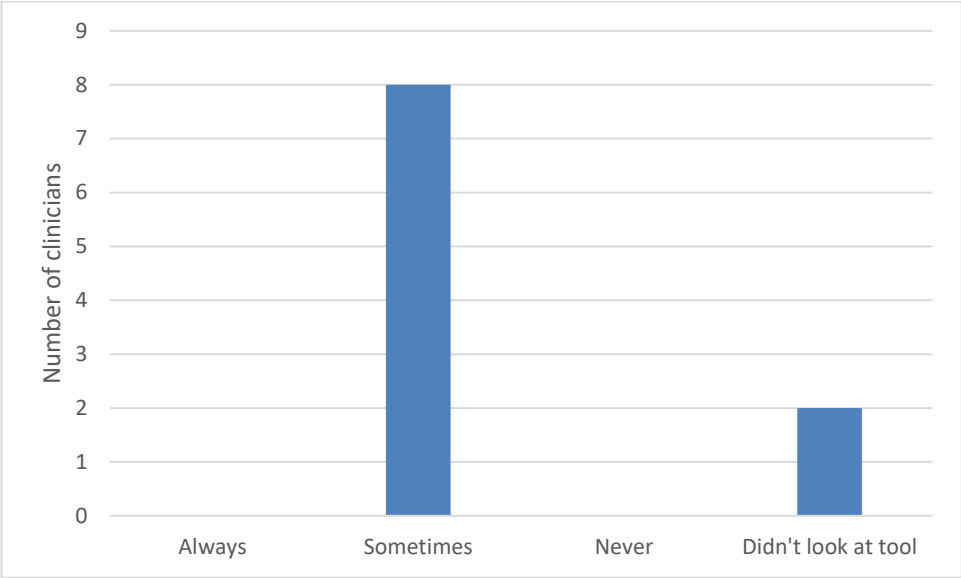
9.3.1.5 If you did use it, was it...



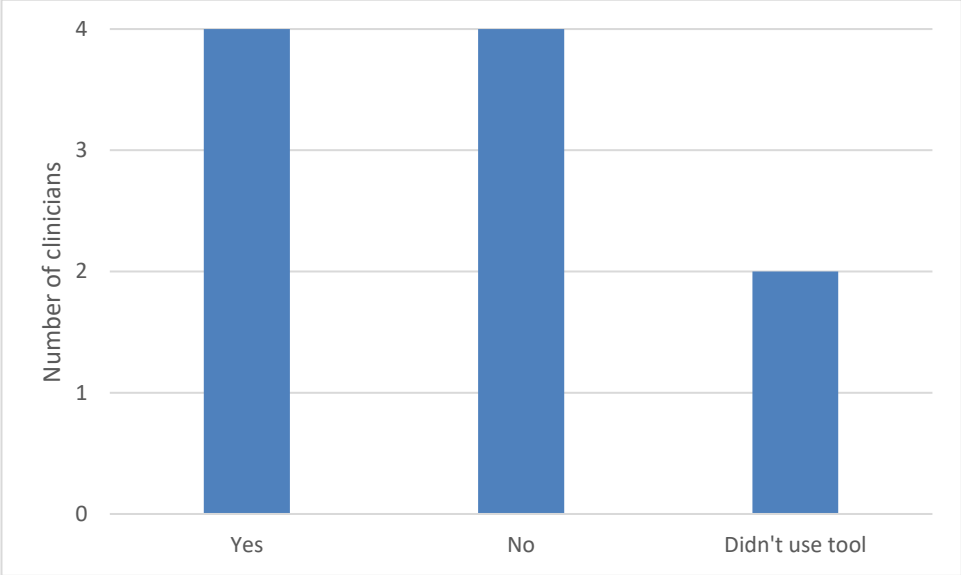
9.3.1.6 Did you use or look at the decision support tool in this cohort of patients?



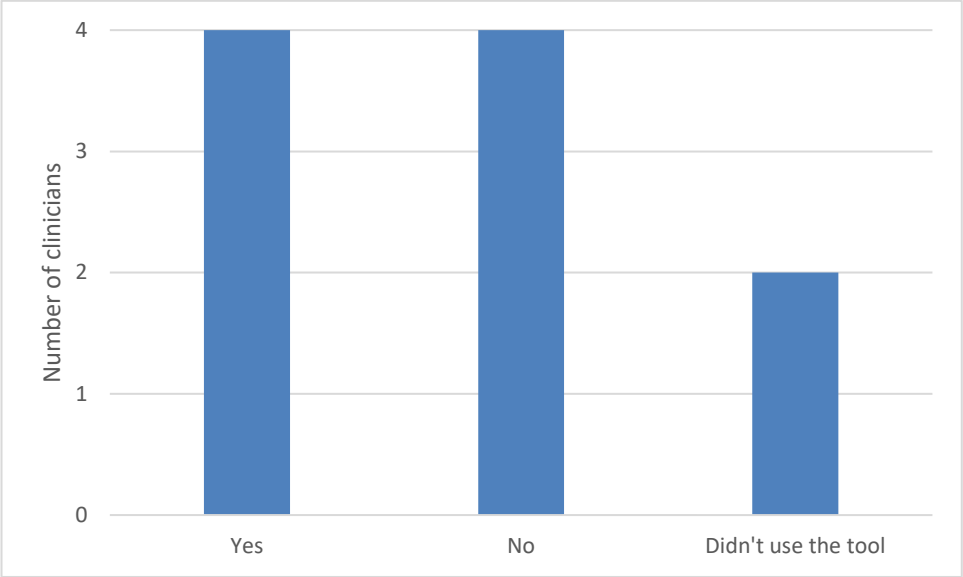
9.3.1.7 If you did look at the decision support tool, did you follow its guidance or recommendation?



9.3.1.8 Did using the decision support tool ever lead to you changing your management plan?



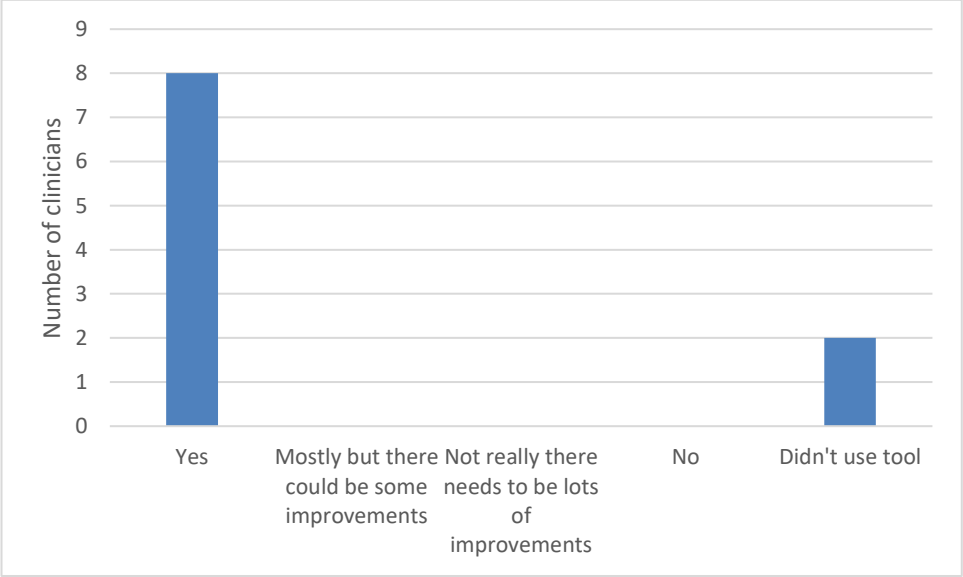
9.3.1.9 Did using the tool ever give you more confidence in proposing a management plan?



9.3.1.10 Which sections or parts of the tool did you find most useful and why?

- Deciding which investigations were most appropriate in different age group
- Contact details for other specialities i.e. Gynaecology Using CRP
- Advice on differentiating between different causes of RIF pain and suggested investigations/management
- Flow diagram
- How to manage the different likeliness of appendicitis

9.3.1.11 Did you find the tool easy to use?



9.3.1.12 Do you have any suggestions for how its usability could be improved?

- More space to formulate impression/differential diagnosis/plan as free text option
- Sometimes I wanted to make a plan that did not follow the plan in the proforma. In such cases perhaps an 'other' option with space to write management plan would be useful and support documentation and explanation of my decision-making process if not a clear-cut case of appendicitis. This may help encourage us to think for ourselves as clinicians and not feel fixed to following a protocol that decides the plan for us. However, for when first approaching the patient with RIF pain this tool is certainly useful and prompts the clerker to think differentials for RIF pain
- More people need to use it - get into the habit of using the standard clerking proforma so don't always see the RIF pain pathway
- 1. Perhaps have it as a smart poster in the office. 2. Any tool requires education of the workforce for its implementation to really be successful. Many other comparable initiatives that I have seen presented have invested in the education process have reported that it is the education process that makes the difference.

9.3.2 Summary of results

11 clinicians responded to the survey. Seven (63.6%) of the respondents were on the SHO grade on call rota. All respondents had worked as a 'day job' or as part of the on-call rota in ASU during the implementation period. Eight clinicians reported using the CDST for RIF pain patients, two did not use it and one did not answer that question. Five clinicians reported using the CDST only when doing the initial clerking, three clinicians reported using it when doing both the initial clerking and when performing the senior review. No clinicians used it only when doing the senior review. Five clinicians reported that they used the CDST on a minority of patients, three clinicians used it on half to most patients and two clinicians on no patients during the study period. When clinicians did look at the support tool, eight respondents felt they sometimes followed its guidance and two respondents reported that they didn't ever look at the tool. Four clinicians reported that the CDST had led them to change their management plan on occasion and four clinicians reported that use of the CDST had given them more confidence in proposing a management plan.

The sections of the CDST that respondents found most useful were spread across the educational content and the suggested investigative pathways. One clinician also mentioned the usefulness of the contact information for other specialties.

All the clinicians who used the CDST found it easy to use. Feedback for improved usability included paperwork design issues (more space in certain sections), a less rigid pathway or at least

the opportunity to deviate from it, more people using the proforma and more of an emphasis on the educational aspect of the pathway.

9.4 Discussion

The survey response rate was 57.9% but this only represented 11 respondents in total. Despite this useful feedback was given. In correlation with the quantitative data from other parts of this study the survey showed that the new proforma and CDST were not used all the time and one respondent did highlight that this was because of defaulting to use of the existing tool. When the new proforma was used, clinicians, especially junior clinicians found it helpful. Junior clinicians were the target demographic. Some clinicians were aware that it changed their investigative or management plan. This corresponds to the quantitative data that shows a significant improvement in the appropriateness of the plans of the junior clinicians when using the new proforma and CDST.

Two important points obtained from this clinician feedback exercise were that more widespread and in-depth education surrounding the topic would be appreciated and, in their opinion, would lead to better uptake and effectiveness of the tool. In addition, some design improvements were suggested.

Chapter 10 Discussion

The pathway of patients under the auspices of acute general surgery is under national focus (2,4,138). It is a high-volume specialty with a subsequent large impact on hospitals and patients. Patients presenting with right iliac fossa (RIF) pain are the largest group presenting to the acute surgical take and are therefore a key demographic to study. There are a wide range of pathologies within this cohort that need to be identified and managed.

10.1 Factors affecting the diagnostic pathway of patients presenting with right iliac fossa pain

Initial assessment of patients presenting is usually done by junior members of the team who are inexperienced in the subtleties of effective and efficient diagnosis (97). This provides a potential intervention point to improve the pathway.

This is the largest study in the literature that looks comprehensively and prospectively at all patients presenting acutely with RIF pain. The limitation of many other studies is that they look retrospectively at patients who have had an appendicectomy (12) which leads to a bias towards patients who fell into a higher clinical suspicion of appendicitis group and were therefore operated on. This study has investigated the most influential factors affecting the diagnostic pathway of patients referred with RIF pain. It has shown that this diagnostic pathway can be positively influenced by a CDST and empower junior clinicians to become more effective decision makers.

10.1.1 **Demographic distribution of patients presenting with right iliac fossa pain**

The large size of this study and its inclusiveness of all patients presenting with RIF pain, gives an accurate and up-to-date picture of the incidence and demographics of the major RIF pain pathologies. The age and gender distribution of patients is similar to those seen in previous studies (12). This study provides new information on the co-morbidity profile of these patients and the distribution between the different referral sources.

10.1.2 **Incidence of pathology**

This study shows that most patients referred to acute general surgical take with RIF pain do not have appendicitis. The incidence of acute appendicitis in our cohort was 31.4%, in accordance with a study by Andersson (139) in 2000 but lower than studies by McCartan (12) and Healy (133).

Appendicitis was more common in men in our study which is also reflected in the literature (12,97,139). The most common definitive diagnosis in men was appendicitis and in women, NSAP. The overall incidence of NSAP was 40.9%, this is at the upper end of the wide range quoted in the literature (11). Referrals stratified by originating source (ED or Primary Care) showed no difference in ultimate definitive diagnoses.

10.1.3 **Risk stratification**

The study has demonstrated the positive and negative predictive values of individual factors involved in the diagnostic process, thereby indicating how much value can be ascribed to each factor. There is no single factor or test that can be used to accurately distinguish between the differential diagnoses of RIF pain.

Sole focus should not be on appendicitis during the diagnostic process, but it remains the pathology that clinicians are most concerned with in this cohort of patients. It is therefore the pathology towards which most of the risk stratification tools are directed. Scoring systems aim to allocate patients into low, medium and high-risk groups depending on the probability of appendicitis with a view to guiding ongoing investigation. Table 33 shows the positive and negative predictive values for the likelihood of appendicitis for the major factors in the pathway that have been examined in this study.

Table 33 Positive and negative predictive values for appendicitis of major factors affecting the RIF pain diagnostic pathway

Metric	**PPV**	**NPV**
Provisional diagnosis (history and examination)	0.47	0.89
WCC and CRP	0.61	0.96
USS	0.89	0.94
CT	0.94	0.99
Alvarado score (≥9) (<5)	0.90	0.94
AIR score (≥9) (<5)	0.89	0.90

This study has shown that it is possible to incorporate the factors proven to inform the diagnostic process and incorporate them into a CDST to guide decision making. This implementation gave a statistically significant improvement in junior clinician decision making after their initial clerking of

patients. We extrapolate that this will improve the patient experience and make the diagnostic pathway more efficient although we have not yet shown an improvement in the time taken from admission to key points along the patient pathway.

10.1.4 **Imaging**

Imaging in general and specifically for RIF pain has evolved in timeliness, accessibility and accuracy over the last decade. With this evolution the attitudes of surgeons towards using it in the diagnostic process have also changed. In the past appendicitis was felt to be a clinical diagnosis and the only decision was whether to take a patient for an appendicectomy. This is no longer standard practice. 62% of patients in this study had imaging. As mentioned previously there are minimal studies looking at the entire cohort of patients presenting with RIF pain and therefore there is little data to make comparisons. In McCarten's study (12) only 36% of patients presenting had imaging, but that was published in 2009 and the use of imaging has increased exponentially since then. The use of ultrasound is widespread, while in UK populations, CT is generally reserved for older patients where other differential diagnoses are seen more often than in younger patients, such as malignancy and diverticular disease. The use of CT notably increased, especially in the United States, after Rao published his notable NEJM paper in 1998.

The rates of USS and CT in this study were 44% and 22% respectively (4% of patients had an USS followed by a CT). McCarten had USS and CT rates of 32% and 4% and again this is accounted for by the increase in the use of CT in the last decade. It is still not clear what the role of MR is for patients presenting acutely with RIF pain. We await the outcome of the registered Cochrane review on the subject (91). There is debate as to the routine imaging of all patients presenting with RIF pain. While some authors are proponents of blanket imaging (137) others suggest caution and that imaging should be used selectively after consideration of the clinical picture first (64,68,128,140,141). Others have also suggested that imaging does not perform as well in the high and low risk probability groups of appendicitis (97). There are ongoing concerns about radiation from CT scans which are difficult to quantify although one study has suggested 0.4% of all cancers in the US may be attributable to radiation from CT scans (98). Proponents of imaging suggest it provides cost benefits to a diagnostic pathway (88,142). However some of these studies only looked at those patients who had an appendicectomy (143) thereby not including the cost of imaging all patients presenting with RIF pain. Lots of studies consider, decreasing the negative appendicectomy rate, as their outcome measure but as is discussed at length elsewhere in this study, this is not necessarily a valid or representative outcome measure especially with the advent of laparoscopy. Besides, many studies have shown that routine CT has failed to decrease negative exploration or perforation rates (128,144).

The other consideration in any pathway is delay to theatre incurred by undertaking imaging. In this study patients (whose eventual diagnosis was appendicitis) who had imaging, took significantly longer to be taken to theatre than those who did not have imaging ($p<0.0001$). Whether this is clinically significant however is not clear as McCarten et al (12) who described the same findings showed that there was no difference between the groups in terms of perforation or post-operative morbidity. Patients going straight to theatre without imaging are likely to have more severe and therefore more clinically obvious appendicitis compared to the imaging group, who are likely to have less severe appendicitis and therefore tolerate a delay to theatre more readily.

10.1.5 **Scoring systems**

This study provides new information on the validity of scoring systems. This was the largest UK validation of the AIR score. The Appendicitis Inflammatory Response score does not outperform the Alvarado score as either a 'rule in' or 'rule out' tool in our cohort. The Alvarado score, the most well-known of the appendicitis scoring systems, has failed to achieve widespread uptake among surgical units. The AIR score has recently been promoted as a more effective risk stratification tool (93,95,97).With these current results it is difficult to imagine that the AIR score will have more success and is therefore unlikely to change practice.

10.2 The clinical decision support tool

The implementation of the clinical decision support tool (CDST) within the RIF pain clerking proforma generated a significant improvement in the decision making of the junior clerking clinician. This was judged by a statistically significant increase in the proportion of senior clinician plans that agreed with the prior junior clinician plan when the RIF proforma and CDST was used.

The diagnosis of appendicitis can be difficult because many pathologies can mimic its signs and symptoms. Any diagnostic pathway involves allocating patients into categories according to the perceived likelihood of them having appendicitis (or another pathology) and then following an appropriate investigation or management process. This might be a formal allocation by using a scoring system but more often it is just a clinical judgement made by an experienced decision maker. The clinical and biochemical elements of any scoring system are the factors which experienced clinicians use to make their diagnostic decisions.

The pre-implementation survey revealed that junior clinicians often observe seniors making diagnostic and management decisions but without an explanation as to why that particular pathway has been followed. Education of juniors as to the elements involved in the decision-

making process should therefore be focused on. The educational content of the RIF proforma aimed to do this whilst also incorporating the key elements used in the scoring systems to guide management in the CDST.

The aim of the imaging algorithm contained within the CDST was to provide a guide to junior clinicians on the most appropriate imaging based on the best available evidence. Through which it was hoped that unnecessary imaging would be avoided, and the most useful imaging would be requested in a prompt time frame without having to wait for a senior review of the patient. This aim was successful. With no change in overall frequency of imaging use when the new proforma was used, a significantly higher proportion of the CTs were requested by junior clinicians.

Further work should look at the cost effectiveness of RIF pain pathways. No formal analysis was done concerning the cost implications of this pathway but there was no obvious increased expense, as there was no difference in the frequency of imaging, the number of operations or the negative appendicectomy rate. There was no difference in length of stay with the new proforma, so no reduction in cost associated with bed days. Healey et al showed there is a high cost associated with managing RIF pain (133). They suggested reducing unnecessary admissions and reducing unnecessary operations. Flum et al showed the significant financial costs incurred by institutions with patients undergoing negative appendicectomy during treatment of presumed appendicitis (145). They both concluded that these factors should be considered when evaluating system-led interventions to improve management such as pathways.

10.3 Negative appendicectomy rates

Traditionally negative appendicectomy rate (NAR) has been used as a key performance indicator of the management of RIF pain. This was straightforward in the age of open appendicectomy when once operative management was decided on an appendicectomy was all but inevitable. Now, diagnostic laparoscopy should be the gold standard in all patients (146).

There is no defined policy as to the management of the macroscopically normal appendix (147). Some would argue that in the presence of other distinct pathology, a normal appendix should be left in situ. When there is no discernible pathology some surgeons would advocate leaving the appendix insitu (147–149) arguing there is the same morbidity associated with removing a normal or inflamed appendix (22). Other authors recommend removing the appendix routinely in this setting (150,151).

It is well described that surgeons now have a lower threshold for taking patients to theatre because laparoscopy can be used as a diagnostic as well as a therapeutic procedure (147).

Diagnostic laparoscopy also presents a diverse cohort of patients. As well as the patients with an acute presentation who are taken to theatre with a suspected diagnosis of appendicitis there are two other groups. The first are those listed above, taken in the acute setting but as a definite diagnostic procedure who are suspected of having NSAP. Then there are the patients with chronic RIF pain with repeat admissions who may benefit from taking the appendix out of the diagnostic equation.

Clearly all these scenarios will influence the negative appendicectomy rate therefore it is no longer a good indicator of successful pre-operative diagnosis and should not be used as an outcome measure.

10.4 Limitations of the study

10.4.1 **Use of the proforma**

The main difficulty faced in execution of this study was take up and use of the new proforma. The existing proforma continued to be in use for almost all other surgical referrals. 'Packs', which are a collection of the necessary medical and nursing admission paperwork are made up by the ward clerk. The pack is picked up by the admitting nurse and the clerking proforma taken from this collection of paperwork by the clerking doctor.

It was thought that it would be easy for the clerking doctor to identify the relevant cohort of patients for the study, because the main inclusion criterion was referral with RIF pain. It was anticipated that the new proforma would just be used instead of the existing proforma in these instances. To facilitate this, the nursing leadership, the nursing staff and the ward clerk team on the acute surgical unit were spoken to and the rationale for the study explained. In addition, what the study hoped to achieve and who the new proforma should be used for was described. Reminder posters were put up in the unit office. Every week all the doctors on call that week were emailed to remind them to use the proforma.

Despite this, the uptake of the proforma was less than expected. Only 44 proformas were used (15%). 248 normal proformas were used during this time. This potential problem had been flagged during the pilot study which was why the above measures were instigated. In addition, although Consultants were in theory supportive of the study, there was not active, obvious encouragement to remind clinicians to use the new proforma. Better 'buy in' from senior clinicians is vital to ensuring the success of this type of study.

There were some other logistical issues associated with use of the proforma. There are scenarios in which no proforma is used. These are when patients are reviewed in the emergency department by the surgical registrar, when seen on the paediatric ward (16 and 17-year olds, referred to the adult general surgeons, but choose paediatric ward) and patients referred from other hospital specialties but already clerked.

10.4.1.1 Potential solutions

On discussion with the staff involved it was found that, the packs are all made up well in advance. Clerking clinicians, especially on a busy on call will almost always pick up a premade pack as they do for all patients. It is extremely difficult to effect a change in behaviour of a well-established routine. Patients with RIF pain form 11.6% of all referrals to the unit therefore a potential solution might be that 'Right Iliac Fossa Pain' packs were also made up in advance and then it would be a case of just picking up the pack from a different pile. In ASU setting, it is all about habit. There were separate abscess clerking proformas at one time which had similar problems with usage. It is the ward clerks who make up these packs and therefore their engagement with the study is vital and targeting them specifically to make up 'RIF pain' packs would be essential in future studies.

Another solution is to show clinicians that it makes a difference, to get more engagement. Presentation of this study to key stakeholders with feedback should accomplish that aim. Another suggestion is having the clinical decision tool and education on an electronic phone or tablet application. Having everything in an 'app' format was considered at the inception of the study. However, there was no funding available at this stage. The decision was made to show effectiveness and then develop an app as a second stage. There is a precedent at the trust with other clinical guideline and decision tools available as apps which have been developed by clinicians in conjunction with the IT department.

Referrals from other specialties will never be on an ASU proforma and have usually had some imaging before referral anyway. The numbers are so small that any work is best focused on the acute surgical unit setting. This work may have applications for paediatric surgery in terms of RIF pain admissions although the pathway there is different, and they will continue to use their standard proforma at present.

The emergency department (ED) was approached at inception of this study and asked to participate. It was suggested that they could use the proforma for any patients presenting with RIF pain and not only would it aid decision making on which pathway patients needed to follow (for example discharge, ambulatory follow up with or without imaging, admission with or without imaging) but also ease the referral and admission process to the surgical team. This is not without

precedent. Examples include fractured neck of femur or chest pain clerking proformas used in the emergency department. ED leadership felt that its use would create extra work given that not all the patients would be admitted. There is the potential for further discussions now the proforma is developed and its impact shown.

10.4.2 **Small numbers**

As has already been commented on in a previous chapter (8.4) the small numbers relating mainly to poor uptake of the proforma limit the conclusions that can be drawn from the results and mean we are not in a position to truthfully understand whether the statistics are robust. The data from this study could be used to inform the design of a future study and for it to be appropriately powered. This along with the above-mentioned solutions to improve proforma use could allow much more confidence in results from future studies in this area.

10.5 Proposal of future work

10.5.1 **Risk Stratification 'Rule out' tool**

Risk stratification is an essential part of developing a pathway for patients with RIF pain, as has been described. A tool that could be used before referral to the surgeons would potentially make the process more efficient and aid referral to the appropriate specialty.

Figure 27 shows the definitive diagnoses of patients who had a WCC and CRP in the normal range and an USS showing no abnormality. The negative predictive value of this combination was 0.98.

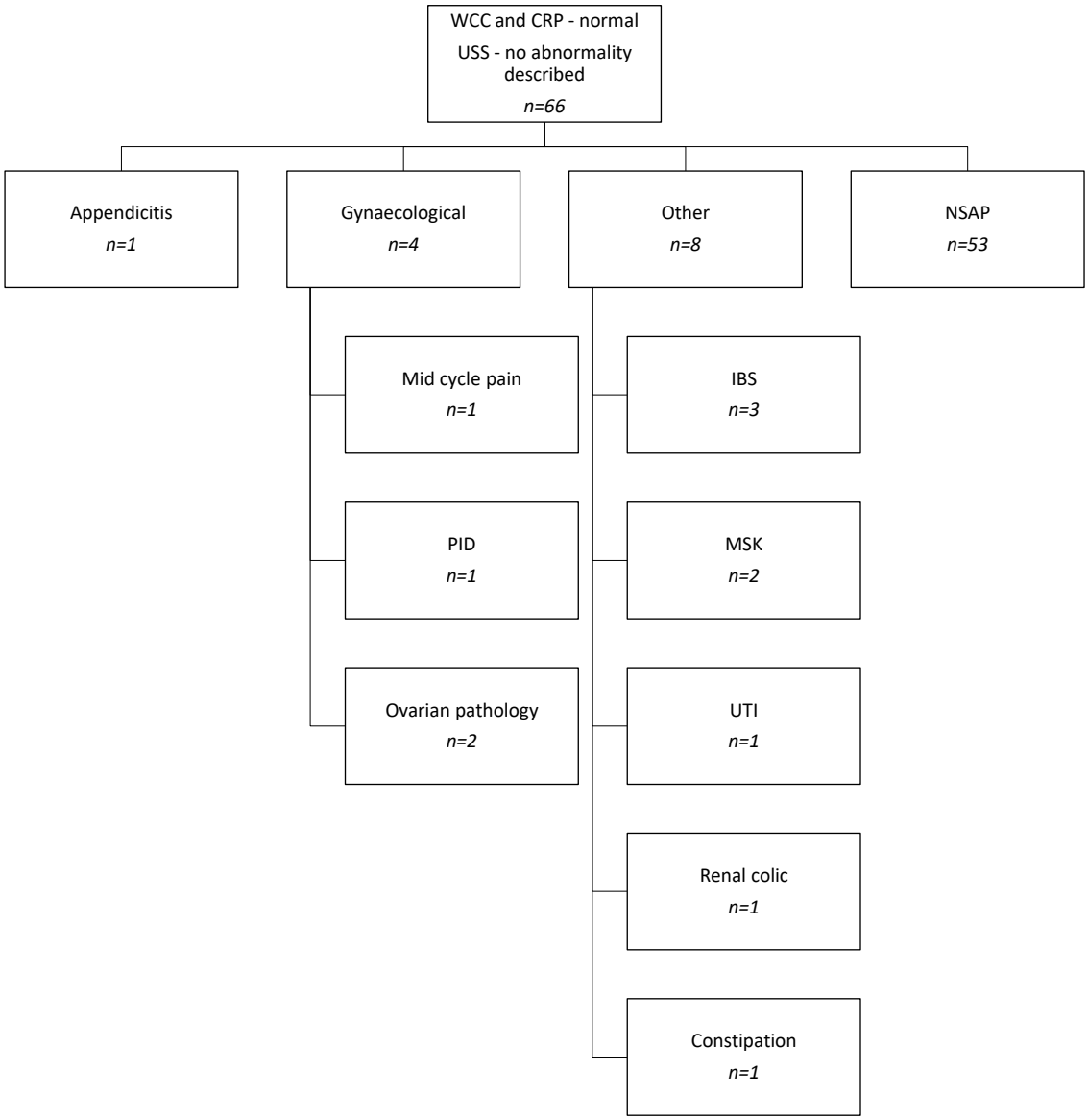


Figure 27 Definitive diagnoses of patients with a normal WCC, normal CRP and normal USS

No abnormality described includes those USS where the appendix could not be visualised. WCC and CRP normal ranges are based on University Hospital Southampton laboratory normal values. WCC – 4.0-11.0. CRP – 0-7.5. Ultrasound scans were undertaken by Sonographers, Radiology Consultants and Specialist Registrars. The ultrasound scanners in use were GE Logiq S8 and E9.

Comparison to the other factors affecting the RIF pain diagnostic pathway can be seen in Table 34. The only test with a better negative predictive value is a CT scan.

Table 34 Negative predictive values of factors used to risk stratify patients presenting with RIF pain

Metric	**NPV**
Provisional diagnosis (history and examination)	0.89
WCC and CRP	0.96
USS	0.94
CT	0.99
Alvarado (≥9) (<5)	0.94
AIR (≥9) (<5)	0.90
Triple negative (WCC, CRP and USS)	**0.98**

A large prospective observational audit is proposed to investigate the effectiveness of combining inflammatory markers and abdominopelvic ultrasound as a 'rule out' tool for appendicitis in patients presenting with RIF pain. The outcomes from this audit could then be used to provide pilot data to power a national trial. In this instance a stepped wedge cluster may be the best trial design (152).

10.5.2 **Further evaluation of CDST**

A further larger study would be of value to see if results of this study could be replicated and if a difference could be shown in any of the secondary outcome measures such as reducing the time from admission to definitive diagnosis or to definitive management. The major limitation of clinician uptake of the new proforma will need to be addressed for any future study to be meaningful. The next step would be adaptation of the CDST and proforma for use in surgical departments in other hospital trusts. Work has been started with another local hospital to this end.

10.6 Conclusions

This study provides new and updated information on the factors affecting the diagnostic pathway of patients presenting with RIF pain. It is the largest study to look at this cohort and is more applicable to current practice than the previous study which was published in 2009 (12).

A novel CDST has been designed and implemented and been shown to significantly improve the decision making of junior clinicians when used within a specific RIF pain pathway. Further work needs to be done with a larger study to look for further improvements to the diagnostic pathway and to understand and improve the poor uptake by junior doctors.

List of References

1. Anderson I, Parks R, Lewis C, Lavelle-Jones M. Emergency General Surgery – a consensus statement. 2017.

2. Anderson I, Eddleston J, Grocott M, Lees N, Lobo D, Loftus I, et al. The Higher Risk General Surgical Patient. 2011.

3. Collins R, Allard S, Anderson I, Barasi S, Boddy S-A, Cheslyn-Curtis S, et al. Emergency Surgery - Standards for unschedules surgical care. 2011.

4. Allum W, Armitage J, Bishop H, Black J, Blair S, Brohi K, et al. Emergency general surgery: the future. 2007.

5. Intensive Care National Audit and Research Centre. ICNARC 2010 [Internet]. Available from: https://www.icnarc.org/Our-Audit/About

6. RCOA. National Emergency Laparotomy Audit [Internet]. Organisational Audit Report. 2014 [cited 2018 Apr 16]. Available from: www.nela.org.uk

7. Digital N. Hospital Episode Statistics Admitted Patient Care [Internet]. [cited 2018 May 5]. Available from: https://digital.nhs.uk/data-and-information/publications/statistical/hospital-admitted-patient-care-activity/2016-17

8. ASGBI. Commissioning guide : 2017.

9. Shelton T, McKinlay R, Schwartz RW. Acute appendicitis: Current diagnosis and treatment. Curr Surg. 2003;60(5):502–5.

10. Humes DJ, Simpson J. Clinical review Acute appendicitis. [cited 2018 May 6]; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1562475/pdf/bmj33300530.pdf

11. Poulin EC, Schlachta CM, Mamazza J. Early laparoscopy to help diagnose acute non-specific abdominal pain. Lancet. 2000;355(9207):861–3.

12. McCartan DP, Fleming FJ, Grace PA. The management of right iliac fossa pain - Is timing everything? Surgeon. 2010;8(4):211–7.

13. O'Connell PR. The vermiform appendix. In: Williams NS, Bulstrode CJ., O'Connell PR, editors. Bailey and Love's Short Practice of Surgery. 25th ed. Hodder Arnold; 2008. p. 1204–5.

14. Moore KL, Agur AMR. Vermiform Appendix. In: Essential Clinical Anatomy. Lippincott, Williams and Wilkins; 1995. p. 109–11.

15. Sandro Cilindro de Souzaa SRMR da C, Iana Goncalves Silva de Souza. Vermiform appendix: positions and length – a study of 377 cases and literature review. J Coloproctology (RIO J) [Internet]. 2015 [cited 2018 May 18];35(4):212–6. Available from: https://ac.els-cdn.com/S2237936315000738/1-s2.0-S2237936315000738-main.pdf?_tid=02a72bd9-9a0c-49cf-be90-1475b59f7510&acdnat=1526678783_0b583826a536d831d332eb7be111da58

16. Prystowsky JB, Pugh CM, Nagle AP. Appendicitis. Curr Probl Surg. 2005;42(10):694–742.

17. Feakins AR, Health B, Trust NHS. Tissue pathways for gastrointestinal and pancreatobiliary pathology. R Coll Pathol [Internet]. 2009;(November):1–38. Available from: http://www.rcpath.org/Resources/RCPath/Migrated Resources/Documents/G/g085giandptissuepathwayfinal.pdf

18. Addiss DG, Shaffer N, Fowler BS, Tauxe R V. THE EPIDEMIOLOGY OF APPENDICITIS AND APPENDECTOMY IN THE UNITED STATES Incidental appendectomies are com- monly performed at the time of other ab- dominal or pelvic surgery to prevent future appendicitis (16). Because the epidemiol- ogy of incidental ap. 1990;132(5):910–25.

19. Petroianu A. Diagnosis of acute appendicitis. Int J Surg [Internet]. 2012;10(3):115–9. Available from: http://dx.doi.org/10.1016/j.ijsu.2012.02.006

20. Graffeo CS, Counselman FL. Appendicitis. Emerg Med Clin North Am [Internet]. 1996 Nov [cited 2018 May 6];14(4):653–71. Available from: http://www.ncbi.nlm.nih.gov/pubmed/8921763

21. Burkitt DP. The aetiology of appendicitis. Br J Surg [Internet]. 1971 Sep 1 [cited 2018 May 6];58(9):695–9. Available from: http://doi.wiley.com/10.1002/bjs.1800580916

22. Bhangu A, Richardson C, Torrance A, Pinkney T, Battersby C, Beral D, et al. Multicentre observational study of performance variation in provision and outcome of emergency appendicectomy. Br J Surg. 2013;100(9):1240–52.

23. Heaton K. Diagnosis of acute non-specific abdominal pain. Lancet [Internet]. 2000 [cited 2018 May 5];355:1644. Available from: https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(05)72545-9.pdf

24. Decadt B, Sussman L, Lewis MPN, Secker A, Cohen L, Rogers C, et al. Randomized clinical trial of early laparoscopy in the management of acute non-specific abdominal pain. Br J Surg [Internet]. 1999 Nov [cited 2018 May 5];86(11):1383–6. Available from: http://www.blackwell-synergy.com/links/doi/10.1046/j.1365-2168.1999.01239.x

25. Gaitán Hernando G, Reveiz L, Farquhar C, Elias Vanessa M. Laparoscopy for the management of acute lower abdominal pain in women of childbearing age. Cochrane Database Syst Rev [Internet]. 2014;(5). Available from: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD007683.pub3/abstract

26. Chao K, Farrell S, Kerdemelidis P, Tulloh B. Diagnostic laparoscopy for chronic right iliac fossa pain: a pilot study. Aust N Z J Surg. 1997;67(11):789–91.

27. Roumen RMH, Groenendijk RPR, Sloots CEJ, Duthoi KES, Scheltinga MRM, Bruijninckx CMA. Randomized clinical trial evaluating elective laparoscopic appendicectomy for chronic right lower-quadrant pain. Br J Surg. 2008;95(2):169–74.

28. Siriwardana RC, Renuka S, Kumarage S. Laparoscopy as a diagnostic and therapeutic option in evaluating chronic unexplained right iliac fossa pain. Surg Endosc Other Interv Tech. 2010;24(11):2793–5.

29. Maggio AQ, Reece-Smith AM, Tang TY, Sadat U, Walsh SR. Early laparoscopy versus active observation in acute abdominal pain: Systematic review and meta-analysis. Int J Surg [Internet]. 2008;6(5):400–3. Available from: http://dx.doi.org/10.1016/j.ijsu.2008.06.004

30. Jones GE, Kreckler S, Shah A, Stechman MJ, Handa A. Increased use of laparoscopy in acute right iliac fossa pain - is it good for patients? Color Dis. 2012;14(2):237–42.

31. De Dombal F, Matharu S, Staniland J, Wilson D. Presentation of cancer to hospital as “acute abdominal pain.” Br J Surg. 1980;67(6):413–6.

32. Korner H, Sondenaa K, Soreide JA, Nysted A, Vatten L. The history is important in patients with suspected acute appendicitis. Dig Surg [Internet]. 2000;17(4):364–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11053944

33. Rasmussen O, Hoffmann J. Assessment of the reliability of symptoms and signs of acute appendicitis.pdf. J R Coll Surg Edinb. 1991;36:372–7.

34. J.V. T, J. G. Leucocyte count and C-reactive protein in the diagnosis of acute appendicitis (multiple letters) [4]. Br J Surg [Internet]. 1999;86(9):1223. Available from:

http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed4&NEWS=N&AN=1999318608

35. Tuggle KRM, Ortega G, Bolorunduro OB, Oyetunji TA, Alexander R, Turner PL, et al. Laparoscopic versus open appendectomy in complicated appendicitis: A review of the NSQIP database. J Surg Res [Internet]. 2010;163(2):225–8. Available from: http://dx.doi.org/10.1016/j.jss.2010.03.071

36. Xharra S, Gashi-Luci L, Xharra K, Veselaj F, Bicaj B, Sada F, et al. Correlation of serum C-reactive protein, white blood count and neutrophil percentage with histopathology findings in acute appendicitis. World J Emerg Surg [Internet]. 2012;7(1):1. Available from: World Journal of Emergency Surgery

37. Cole MA, Maldonado N. Evidence-based management of suspected appendicitis in the emergency department. Emerg Med Pract [Internet]. 2011 Oct [cited 2018 May 6];13(10):1–29; quiz 29. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22164515

38. Ortega-Deballon P, Ruiz de Adana-Belbel JC, Hernández-Matías A, García-Septiem J, Moreno-Azcoita M. Usefulness of laboratory data in the management of right iliac fossa pain in adults. Dis Colon Rectum [Internet]. 2008 Jul [cited 2018 May 6];51(7):1093–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18484138

39. Andersson REB. Meta-analysis of the clinical and laboratory diagnosis of appendicitis. Br J Surg [Internet]. 2004;91(1):28–37. Available from: http://doi.wiley.com/10.1002/bjs.4464

40. Goodwin a T, Swift RI, Bartlett MJ, Fernando BS, Chadwick SJ. Can serum interleukin-6 levels predict the outcome of patients with right iliac fossa pain? Ann R Coll Surg Engl [Internet]. 1997;79(2):130–3. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2502817&tool=pmcentrez&rendertype=abstract

41. Gurleyik G, Gurleyik E, Cetinkaya F, Unalmiser S. Serum interleukin-6 measurement in the diagnosis of acute appendicitis. ANZ J Surg [Internet]. 2002;72:665–7. Available from: http://dx.doi.org/10.1046/j.1445-2197.2002.02516.x

42. Yu CW, Juan LI, Wu MH, Shen CJ, Wu JY, Lee CC. Systematic review and meta-analysis of the diagnostic accuracy of procalcitonin, C-reactive protein and white blood cell count for suspected acute appendicitis. Br J Surg. 2013;100(3):322–9.

43. Paajanen H, Mansikka A, Laato M, Ristamaki R, Pulkki K, Kostiainen S. Novel serum

inflammatory markers in acute appendicitis. Scand J Clin Lab Invest [Internet]. 2002;62(8):579–84. Available from: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12564616

44. Burcharth J, Pommergaard H, Rosenberg J, Gogenur I. HYPERBILIRUBINEMIA AS A PREDICTOR FOR APPENDICEAL PERFORATION: A SYSTEMATIC REVIEW. Scand J Surg [Internet]. 2013 [cited 2018 May 6];102:55–60. Available from: http://journals.sagepub.com/doi/pdf/10.1177/1457496913482248

45. Thuijls G, Derikx JPM, Prakken FJ, Huisman B, Van Bijnen Ing AA, Van Heurn ELWE, et al. A pilot study on potential new plasma markers for diagnosis of acute appendicitis. Am J Emerg Med [Internet]. 2011;29(3):256–60. Available from: http://dx.doi.org/10.1016/j.ajem.2009.09.029

46. Tschuor C, Raptis DA, Limani P, Bächler T, Oberkofler CE, Breitenstein S, et al. The value of pancreatic stone protein in predicting acute appendicitis in patients presenting at the emergency department with abdominal pain. BMC Gastroenterol. 2012;12.

47. Duzgun AP, Bugdayci G, Sayin B, Ozmen MM, Ozer MV, Coskun F. Serum D-lactate: a useful diagnostic marker for acute appendicitis. Hepatogastroenterology [Internet]. [cited 2018 May 6];54(77):1483–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17708281

48. Kaya B, Sana B, Eris C, Karabulut K, Bat O, Kutanis R. The diagnostic value of D-dimer, procalcitonin and CRP in acute appendicitis. Int J Med Sci. 2012;9(10):909–15.

49. Schellekens DHSM, Hulsewé KWE, van Acker BAC, van Bijnen AA, de Jaegere TMH, Sastrowijoto SH, et al. Evaluation of the Diagnostic Accuracy of Plasma Markers for Early Diagnosis in Patients Suspected for Acute Appendicitis. Lewis L, editor. Acad Emerg Med [Internet]. 2013 Jul 1 [cited 2018 May 6];20(7):703–10. Available from: http://doi.wiley.com/10.1111/acem.12160

50. Albayrak Y, Albayrak A, Albayrak F, Yildirim R, Aylu B, Uyanik A, et al. Mean Platelet Volume: A New Predictor in Confirming Acute Appendicitis Diagnosis. [cited 2018 May 6]; Available from: http://journals.sagepub.com/doi/pdf/10.1177/1076029610364520

51. Gronroos, J.M. , Forsstrom, J.J., Irjala, K., Nevalainenet TJ. Phospholipase A2, C-reactive protein, and white blood cell count in the diagnosis of acute apendicitis. Clin Chem. 1994;40(9):1757–60.

52. Eriksson S, Granström L, Olander B, Pira U. Leucocyte elastase as a marker in the diagnosis of acute appendicitis. Eur J Surg [Internet]. 1995 Dec [cited 2018 May 6];161(12):901–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/8775633

53. Ozdogan M, Devay AO, Gurer A, Ersoy E, Devay SD, Kulacoglu H, et al. Plasma total anti-oxidant capacity correlates inversely with the extent of acute appendicitis: a case control study. [cited 2018 May 6]; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1475839/pdf/1749-7922-1-6.pdf

54. Oztürk ZA, Köklü S, Erol MF, Yilmaz FM, Basar O, Yüksel O, et al. Serum adenosine deaminase levels in diagnosis of acute appendicitis. Emerg Med J [Internet]. 2008 Sep 1 [cited 2018 May 6];25(9):583–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18723708

55. C B, Şerban D, Şavlovschi C, Am D, Kraft A. Lipopolysaccharide binding protein (L.B.P.) – an inflammatory marker of prognosis in the acute appendicitis. J Med Life [Internet]. 2012 [cited 2018 May 6];5(3):342–7. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3487177/pdf/JMedLife-05-342.pdf

56. Pennington C, Dunn J, Li C, Ha T, Browder W. Nuclear factor kappaB activation in acute appendicitis: a molecular marker for extent of disease? Am Surg [Internet]. 2000 Oct [cited 2018 May 6];66(10):914–8; discussion 918-9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/11261616

57. Smart NJ, Hyde C, Winyard PG, Shaw AM, Daniels IR. Biomarkers for diagnosis of acute appendicitis in adults. Cochrane Database Syst Rev. 2015;2015(3).

58. Flum DR, McClure TD, Morris A, Koepsell T. Misdiagnosis of appendicitis and the use of diagnostic imaging. J Am Coll Surg. 2005;201(6):933–9.

59. Leeuwenburgh MMN, Jensch S, Gratama JWC, Spilt A, Wiarda BM, Van Es HW, et al. MRI features associated with acute appendicitis. Eur Radiol. 2014;24(1):214–22.

60. Leeuwenburgh MMN, Laméris W, van Randen A, Bossuyt PMM, Boermeester MA, Stoker J. Optimizing imaging in suspected appendicitis (OPTIMAP-study): A multicenter diagnostic accuracy study of MRI in patients with suspected acute appendicitis. Study Protocol. BMC Emerg Med [Internet]. 2010;10(1):19. Available from: http://www.biomedcentral.com/1471-227X/10/19

61. Leeuwenburgh MMN, Wiezer MJ, Wiarda BM, Bouma WH, Phoa SSKS, Stockmann HBAC, et

al. Accuracy of MRI compared with ultrasound imaging and selective use of CT to discriminate simple from perforated appendicitis. Br J Surg. 2014;101(1):147–55.

62. April MD, Long B. What Is the Diagnostic Accuracy of Magnetic Resonance Imaging for Acute Appendicitis? 2017 [cited 2018 May 7]; Available from: https://www.annemergmed.com/article/S0196-0644(17)31663-3/pdf

63. Iliac Fossa Pain (Acute Right). [cited 2018 May 6]; Available from: http://www.imagingpathways.health.wa.gov.au/index.php/imaging-pathways/gastrointestinal/acute-abdomen/acute-right-iliac-fossa-pelvic-pain#pathway

64. Ünlü Ç, de Castro SMM, Tuynman JB, Wüst AF, Steller EP, van Wagensveld BA. Evaluating routine diagnostic imaging in acute appendicitis. Int J Surg. 2009;7(5):451–5.

65. Doria AS, Moineddin R, Kellenberger CJ, Epelman M, Beyene J, Schuh S, et al. US or CT for Diagnosis of Appendicitis in Children and Adults? A Meta-Analysis. Radiology [Internet]. 2006;241(1):83–94. Available from: http://pubs.rsna.org/doi/10.1148/radiol.2411050913

66. Balthazar EJ, Birnbaum BA, Yee J, Megibow AJ, Roshkow J, Gray C. Acute appendicitis: CT and US correlation in 100 patients. Radiology [Internet]. 1994 Jan 1 [cited 2018 May 6];190(1):31–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/8259423

67. Styrud J, Eriksson S, Nilsson I, Ahlberg G, Haapaniemi S, Neovius G, et al. Appendectomy versus antibiotic treatment in acute appendicitis. A prospective multicenter randomized controlled trial. World J Surg. 2006;30(6):1033–7.

68. Horton MD, Counter SF, Florence MG, Hart MJ. 2000 A prospective trial of computed tomography and ultrasonography for diagnosing appendicitis in the atypical patient and comment.pdf. 2000;1999–2001.

69. Poortman P, Oostvogel HJM, Bosma E, Lohle PNM, Cuesta MA, de Lange-de Klerk ESM, et al. Improving Diagnosis of Acute Appendicitis: Results of a Diagnostic Pathway with Standard Use of Ultrasonography Followed by Selective Use of CT. J Am Coll Surg [Internet]. 2009;208(3):434–41. Available from: http://dx.doi.org/10.1016/j.jamcollsurg.2008.12.003

70. Birnbaum BA, Wilson SR. Appendicitis at the Millennium. Radiology [Internet]. 2000 May 1 [cited 2018 May 7];215(2):337–48. Available from: http://pubs.rsna.org/doi/10.1148/radiology.215.2.r00ma24337

71. Puylaert JB. Acute appendicitis: US evaluation using graded compression. Radiology [Internet]. 1986 Feb 1 [cited 2018 May 7];158(2):355–60. Available from: http://www.ncbi.nlm.nih.gov/pubmed/2934762

72. Bondi M, Miller R, Zbar A, Hazan Y, Appelman Z, Capsi B, et al. Improving the diagnostic accuracy of ultrasonography in suspected acute appendicitis by the combined transabdominal and transvaginal approach. Am Surg. 2012;78(1):98–103.

73. Wan MJ, Krahn M, Ungar WJ, Ç aku E, Sung L, Santiago Medina L, et al. Acute Appendicitis in Young Children: Cost-effectiveness of US versus CT in Diagnosis—A Markov Decision Analytic Model 1. [cited 2018 May 7]; Available from: https://pubs.rsna.org/doi/pdf/10.1148/radiol.2502080100

74. Cogbill TH, Jarman BT. Preface. Surg Clin North Am [Internet]. 2011 Feb [cited 2018 May 7];91(1):xv–xvi. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21184897

75. Avanesov M, Jesper Wiese N, Karul M, Guerreiro H, Keller S, Busch P, et al. Diagnostic prediction of complicated appendicitis by combined clinical and radiological appendicitis severity index (APSI). [cited 2018 May 7]; Available from: https://doi.org/10.1007/s00330-018-5339-9

76. Chin CM, Lim KL. Appendicitis: Atypical and Challenging CT Appearances. [cited 2018 May 7]; Available from: https://pubs.rsna.org/doi/suppl/10.1148/rg.351140122/suppl_file/351140122supp.pdf

77. Rao PM, Rhea JT, Novelline RA, Mostafavi AA, McCabe CJ. Effect of Computed Tomography of the Appendix on Treatment of Patients and Use of Hospital Resources. N Engl J Med [Internet]. 1998;338(3):141–6. Available from: http://www.nejm.org/doi/abs/10.1056/NEJM199801153380301

78. Yoon HM, Chong &, Suh H, Cho YA, Kim JR, Lee JS, et al. The diagnostic performance of reduced-dose CT for suspected appendicitis in paediatric and adult patients: A systematic review and diagnostic meta-analysis. Eur Radiol [Internet]. 2018 [cited 2018 May 7];28:2537–48. Available from: https://doi.org/10.1007/s00330-017-5231-z

79. Repplinger MD, Pickhardt PJ, Robbins JB, Kitchin DR, Ziemlewicz TJ, Hetzel SJ, et al. Prospective Comparison of the Diagnostic Accuracy of MR Imaging versus CT for Acute Appendicitis. Radiology [Internet]. 2018 Apr 24 [cited 2018 May 7];171838. Available from: http://pubs.rsna.org/doi/10.1148/radiol.2018171838

80. Martin JF, Mathison DJ, Mullan PC, Otero HJ. Secondary imaging for suspected appendicitis after equivocal ultrasound: time to disposition of MRI compared to CT. [cited 2018 May 7]; Available from: https://link.springer.com/content/pdf/10.1007%2Fs10140-017-1570-y.pdf

81. Duke E, Kalb B, Arif-Tiwari H, Daye ZJ, Gilbertson-Dahdal D, Keim SM, et al. A Systematic Review and Meta-Analysis of Diagnostic Performance of MRI for Evaluation of Acute Appendicitis. Am J Roentgenol [Internet]. 2016 Mar 22 [cited 2018 May 7];206(3):508–17. Available from: http://www.ajronline.org/doi/10.2214/AJR.15.14544

82. Curtin KR, Fitzgerald SW, Nemcek Jr. AA, Hoff FL, Vogelzang RL. CT diagnosis of acute appendicitis: Imaging findings. Am J Roentgenol. 1995;164(4).

83. Nelson DW, Causey MW, Porta CR, McVay DP, Carnes AM, Johnson EK, et al. Examining the relevance of the physician's clinical assessment and the reliance on computed tomography in diagnosing acute appendicitis. Am J Surg [Internet]. 2013;205(4):452–6. Available from: http://dx.doi.org/10.1016/j.amjsurg.2012.07.038

84. Ujiki MB, Murayama KM, Cribbins AJ, Angelos P, Dawes L, Prystowsky JB, et al. CT scan in the management of acute appendicitis. J Surg Res. 2002;105(2):119–22.

85. van Breda Vriesman AC, Kole BJ, Puylaert JBCM. Effect of ultrasonography and optional computed tomography on the outcome of appendectomy. Eur Radiol. 2003;13(10):2278–82.

86. Cho CS, Buckingham JM, Pierce M, Hardman DT. COMPUTED TOMOGRAPHY IN THE DIAGNOSIS OF EQUIVOCAL APPENDICITIS. ANZ J Surg [Internet]. 1999 Sep 1 [cited 2018 May 6];69(9):664–7. Available from: http://doi.wiley.com/10.1046/j.1440-1622.1999.01660.x

87. Bendeck SE, Nino-Murcia M, Berry GJ, Jeffrey RB. Imaging for Suspected Appendicitis: Negative Appendectomy and Perforation Rates. Radiology [Internet]. 2002;225(1):131–6. Available from: http://pubs.rsna.org/doi/10.1148/radiol.2251011780

88. Romero J, Sanabria A, Angarita M, Varón JC. Cost-effectiveness of computed tomography and ultrasound in the diagnosis of appendicitis. Biomedica [Internet]. 2008;28(1):139–47. Available from: http://www.ncbi.nlm.nih.gov/pubmed/18645669

89. Raman SS, Lu DSK, Kadell BM, Vodopich DJ, Sayre J, Cryer H. Accuracy of Nonfocused Helical CT for the Diagnosis of Acute Appendicitis: A 5-Year Review. Am J Roentgenol [Internet]. 2002 Jun 23 [cited 2018 May 6];178(6):1319–25. Available from:

http://www.ajronline.org/doi/10.2214/ajr.178.6.1781319

90. Rud B. Diagnostic accuracy of Computed Tomography for Appendicitis in Adults Protocol information Plain language summary. 2013;(7):1–13.

91. D'Souza et al. Cochrane Database of Systematic Reviews Magnetic resonance imaging (MRI) for diagnosis of acute appendicitis (Protocol) Magnetic resonance imaging (MRI) for diagnosis of acute appendicitis (Protocol). Cochrane Database Syst Rev Art [Internet]. 2016;(1). Available from: www.cochranelibrary.com

92. Wild J, Abdul N, Ritchie J, Bo R, Freels S, Nelson R. Ultrasonography for Diagnosis of Acute Appendicitis (Protocol). Cochrane Database Syst Rev. 2013;(2).

93. Andersson M, Andersson RE. The appendicitis inflammatory response score: A tool for the diagnosis of acute appendicitis that outperforms the Alvarado score. World J Surg. 2008;32(8):1843–9.

94. Ohle R, O'Reilly F, O'Brien KK, Fahey T, Dimitrov BD. The Alvarado score for predicting acute appendicitis: A systematic review. BMC Med [Internet]. 2011;9(1):139. Available from: http://www.biomedcentral.com/1741-7015/9/139

95. Castro SMM De, Ünlü Ç, Steller EP, Van Wagensveld BA, Vrouenraets BC. Evaluation of the appendicitis inflammatory response score for patients with acute appendicitis. World J Surg. 2012;36(7):1540–5.

96. Tan WJ, Pek W, Kabir T, Goh YC, Chan WH, Wong WK, et al. Alvarado score: A guide to computed tomography utilization in appendicitis. ANZ J Surg. 2013;83(10):748–52.

97. Scott AJ, Mason SE, Arunakirinathan M, Reissis Y, Kinross JM, Smith JJ. Risk stratification by the Appendicitis Inflammatory Response score to guide decision-making in patients with suspected appendicitis. Br J Surg. 2015;102(5):563–72.

98. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277–84.

99. Parasyn AD, Truskett PG, Bennett M, Lum S, Barry J, Haghighi K, et al. Acute-care surgical service: A change in culture. ANZ J Surg. 2009;79(1–2):12–8.

100. Cox MR, Cook L, Dobson J, Lambrakis P, Ganesh S, Cregan P. Acute surgical unit: A new model of care. ANZ J Surg. 2010;80(6):419–24.

101. Truskett P. Acute Surgical units: the future face of emergency surgery. ANZ J Surg. 2010;80(7–8):477–8.

102. Von Conrady D, Hamza S, Weber D, Kalani K, Epari K, Wallace M, et al. The acute surgical unit: Improving emergency care. ANZ J Surg. 2010;80(12):933–6.

103. Beardsley CJ, Sandhu T, Gubicak S, Srikanth S V., Galketiya KP, Piscioneri F. A model-based evaluation of the Canberra Hospital Acute Care Surgical Unit - Acute care surgery: A case of one size fits all? Surg Today. 2014;44(5):884–7.

104. Brockman SF, Scott S, Guest GD, Stupart DA, Ryan S, Watters DAK. Does an Acute Surgical Model increase the rate of negative appendicectomy or perforated appendicitis? ANZ J Surg. 2013;83(10):744–7.

105. Stupart DA, Watters DA, Guest GD, Cuthbert V, Ryan S. Dedicated emergency theatres improve service delivery and surgeons' job satisfaction. ANZ J Surg. 2013;83(7–8):549–53.

106. Suen K, Hayes IP, Thomson BNJ, Shedda S. Effect of the introduction of an emergency general surgery service on outcomes from appendicectomy. Br J Surg. 2014;101(1):141–6.

107. Lancashire JF, Steele M, Parker D, Puhalla H. Introduction of an acute surgical unit: Comparison of performance indicators and outcomes for operative management of acute appendicitis. World J Surg. 2014;38(8):1947–53.

108. Poole GH, Glyn T, Srinivasa S, Hill AG. Modular acute system for general surgery: Hand over the operation, not the patient. ANZ J Surg. 2012;82(3):156–60.

109. Perry E, MacKintosh S, Connor S. Role of an acute assessment and review area for general surgical patients. ANZ J Surg. 2010;80(6):425–9.

110. Hsee L, Devaud M, Middelberg L, Jones W, Civil I. Acute Surgical Unit at Auckland City Hospital: A descriptive analysis. ANZ J Surg. 2012;82(9):588–91.

111. Sorelli PG, El-Masry NS, Dawson PM, Theodorou NA. The dedicated emergency surgeon: Towards consultant-based acute surgical admissions. Ann R Coll Surg Engl. 2008;90(2):104–8.

112. Tincknell L, Burton S, Cooke C, Black S, Andreant S, Jourdan I, et al. The emergency surgical team - The way forward in emergency care? Ann R Coll Surg Engl. 2009;91(1):18–22.

113. Moore LJ, Turner KL, Jones SL, Fahy BN, Moore FA. Availability of acute care surgeons

improves outcomes in patients requiring emergent colon surgery. Am J Surg [Internet]. 2011;202(6):837–42. Available from: http://dx.doi.org/10.1016/j.amjsurg.2011.07.006

114. Miller PR, Wildman EA, Chang MC, Meredith JW. Acute care surgery: Impact on practice and economics of elective surgeons. J Am Coll Surg [Internet]. 2012;214(4):531–5. Available from: http://dx.doi.org/10.1016/j.jamcollsurg.2011.12.045

115. Matsushima K, Cook A, Tollack L, Shafi S, Frankel H. An acute care surgery model provides safe and timely care for both trauma and emergency general surgery patients. J Surg Res [Internet]. 2011;166(2):e143–7. Available from: http://dx.doi.org/10.1016/j.jss.2010.11.922

116. Maa J, Carter JT, Gosnell JE, Wachter R, Harris HW. The Surgical Hospitalist: A New Model for Emergency Surgical Care. J Am Coll Surg. 2007;205(5):704–11.

117. Garland AM, Riskin DJ, Brundage SI, Moritz F, Spain DA, Purtill MA, et al. A county hospital surgical practice: a model for acute care surgery. Am J Surg. 2007;194(6):758–64.

118. Ciesla DJ, Cha JY, Smith JS, Llerena LE, Smith DJ. Implementation of an acute care surgery service at an academic trauma center. Am J Surg [Internet]. 2011;202(6):779–86. Available from: http://dx.doi.org/10.1016/j.amjsurg.2011.06.046

119. Britt RC, Weireter LJ, Britt LD. Initial Implementation of an Acute Care Surgery Model: Implications for Timeliness of Care. J Am Coll Surg [Internet]. 2009;209(4):421–4. Available from: http://dx.doi.org/10.1016/j.jamcollsurg.2009.06.368

120. Ball CG, MacLean AR, Dixon E, Quan ML, Nicholson L, Kirkpatrick AW, et al. Acute care surgery: The impact of an acute care surgery service on assessment, flow, and disposition in the emergency department. Am J Surg [Internet]. 2012;203(5):578–82. Available from: http://dx.doi.org/10.1016/j.amjsurg.2011.12.006

121. Faryniuk AM, Hochman DJ. Effect of an acute care surgical service on the timeliness of care. Can J Surg. 2013;56(3):187–91.

122. Morad Hameed S, Brenneman FD, Ball CG, Pagliarello J, Razek T, Parry N, et al. General surgery 2.0: The emergence of acute care surgery in Canada. Can J Surg. 2010;53(2):79–83.

123. GSA. 12 Point Plan. 2010.

124. Liu J, Wyatt JC, Altman DG. Decision tools in health care: Focus on the problem, not the

solution. BMC Med Inform Decis Mak. 2006;6:1–7.

125. Liu JLY, Wyatt JC, Deeks JJ, Clamp S, Keen J, Verde P, et al. Systematic reviews of clinical decision tools for acute abdominal pain. Health Technol Assess. 2006;10(47):1–167, iii–iv.

126. Arksey H, O'Malley L. Scoping studies: Towards a methodological framework. Int J Soc Res Methodol Theory Pract. 2005;8(1):19–32.

127. Armstrong R, Hall BJ, Doyle J, Waters E. "Scoping the scope" of a cochrane review. J Public Health (Bangkok). 2011;33(1):147–50.

128. Lee CC, Golub R, Singer AJ, Cantu R, Levinson H. Routine versus Selective Abdominal Computed Tomography Scan in the Evaluation of Right Lower Quadrant Pain: A Randomized Controlled Trial. Acad Emerg Med. 2007;14(2):117–22.

129. de Dombal FT. Acute abdominal pain--an O.M.G.E. survey. Scand J Gastroenterol Suppl. 1979;56:29–43.

130. Irvin TT. Abdominal pain: a surgical audit of 1190 emergency admissions. Br J Surg. 1989 Nov;76(11):1121–5.

131. Raheja SK, Student M, Mcdonald PJ. Non-specific abdominal pain -an expensive mystery. J R Soc Med. 1990;83.

132. Decadt B, Sussman L, Lewis MP, Secker a, Cohen L, Rogers C, et al. Randomized clinical trial of early laparoscopy in the management of acute non-specific abdominal pain. Br J Surg [Internet]. 1999;86(11):1383–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10583282

133. Healy DA, Aziz A, Wong M, Clarke Moloney M, Coffey JC, Grace PA, et al. A descriptive cost analysis study of cases of right iliac fossa pain. Int J Surg [Internet]. 2013;11(7):524–8. Available from: http://dx.doi.org/10.1016/j.ijsu.2013.05.001

134. Debnath J, Sharma V, Chatterjee S. Diagnosing acute appendicitis: Is there any role of ultrasonography? Am J Surg [Internet]. 2014;207(6):1000–1. Available from: http://dx.doi.org/10.1016/j.amjsurg.2013.05.013

135. Wise SW, Labuski MR, Kasales CJ, Blebea JS, Meilstrup JW, Holley GP, et al. Comparative assessment of CT and sonographic techniques for appendiceal imaging. Am J Roentgenol. 2001;176(4):933–41.

136. Gammeri E, Catton A, Van Duren B, Appleton S, Van Boxel G. Towards an evidence-based management of right iliac fossa pain in the over 50-year-old patient.

137. Drake FT, Flum DR. Improvement in the Diagnosis of Appendicitis. [cited 2018 May 16]; Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4214266/pdf/nihms636080.pdf

138. Symons NRA, Moorthy K, Almoudaris AM, Bottle A, Aylin P, Vincent CA, et al. Mortality in high-risk emergency general surgical admissions. Br J Surg. 2013;100(10):1318–25.

139. Andersson RE, Hugander A, Ravn H, Offenbartl K, Ghazi SH, Nyström PO, et al. Repeated Clinical and Laboratory Examinations in Patients with an Equivocal Diagnosis of Appendicitis. World J Surg. 2000;24:479–85.

140. Hong JJ, Cohn SM, Ekeh AP, Newman M, Salama M, Leblang SD. A Prospective Randomized Study of Clinical Assessment versus Computed Tomography for the Diagnosis of Acute Appendicitis. Surg Infect (Larchmt) [Internet]. 2003 Sep [cited 2018 Jun 1];4(3):231–9. Available from: http://www.liebertonline.com/doi/abs/10.1089/109629603322419562

141. Gwynn LK. The diagnosis of acute appendicitis: clinical assessment versus computed tomography evaluation. J Emerg Med [Internet]. 2001;21(2):119–23. Available from: http://www.sciencedirect.com/science/article/pii/S0736467901003535

142. Lahaye MJ, Lambregts DMJ, Mutsaers E, Essers BAB, Breukink S, Cappendijk VC, et al. Mandatory imaging cuts costs and reduces the rate of unnecessary surgeries in the diagnostic work-up of patients suspected of having appendicitis. Eur Radiol. 2015;25(5):1464–70.

143. D'Souza N, Marsden M, Bottomley S, Nagarajah N, Scutt F, Toh S. Cost-effectiveness of routine imaging of suspected appendicitis. Ann R Coll Surg Engl. 2018;100(1):47–51.

144. Lopez PP, Cohn SM, Popkin CA, Jackowski J, Michalek JE, Appendicitis Diagnostic Group. The use of a computed tomography scan to rule out appendicitis in women of childbearing age is as accurate as clinical examination: a prospective randomized trial. Am Surg. 2007 Dec;73(12):1232–6.

145. Flum DR, Koepsell T. The clinical and economic correlates of misdiagnosed appendicitis: nationwide analysis. Arch Surg. 2002;137(7):799–804; discussion 804.

146. Sauerland S, Agresta F, Bergamaschi R, Borzellino G, Budzynski A, Champault G, et al.

Laparoscopy for abdominal emergencies: Evidence-based guidelines of the European Association for Endoscopic Surgery. Surg Endosc Other Interv Tech. 2006;20(1):14–29.

147. Lee M, Paavana T, Mazari F, Wilson TR. The morbidity of negative appendicectomy. Ann R Coll Surg Engl. 2014;96(7):517–20.

148. Teh SH, O'Ceallaigh S, Mckeon JG, O'Donohoe MK, Tanner W a, Keane FB. Should an appendix that looks "normal" be removed at diagnostic laparoscopy for acute right iliac fossa pain? Eur J Surg [Internet]. 2000;166(5):388–9. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10881950

149. Walker SJ, West CR, Colmer MR. Acute appendicitis: Does removal of a normal appendix matter, what is the value of diagnostic accuracy and is surgical delay important? Ann R Coll Surg Engl. 1995;77(5):358–63.

150. Ekeh AP, Wozniak CJ, Monson B, Crawford J, McCarthy MC. Laparoscopy in the contemporary management of acute appendicitis. Am J Surg. 2007;193(3):310–4.

151. Strong S, Blencowe N, Bhangu A, Panagiotopoulou IG, Chatzizacharias N, Rana M, et al. How good are surgeons at identifying appendicitis? Results from a multi-centre cohort study. Int J Surg [Internet]. 2015;15:107–12. Available from: http://dx.doi.org/10.1016/j.ijsu.2015.01.032

152. Hemming K, Haines TP, Chilton PJ, Girling AJ, Lilford RJ. The stepped wedge cluster randomised trial: rationale, design, analysis, and reporting. Bmj [Internet]. 2015;350(feb06 1):h391–h391. Available from: http://www.bmj.com/cgi/doi/10.1136/bmj.h391