**Title page**

**Title:**

The ‘Empty Pelvis Syndrome’: A systematic review of reconstruction techniques and their associated complications.

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**Abstract**

**Aim:**

‘Empty pelvis syndrome’ is a major contributor to morbidity following pelvic exenteration. Several techniques aimed at filling the pelvis have been proposed, however, there is no consensus on the best approach. We evaluated and compared the complications associated with each reconstruction technique to determine which is associated with the lowest incidence of complications related to the ‘empty pelvis’.

**Methods:**

The systematic review protocol was prospectively registered with PROSPERO (CRD42021239307). PRISMA-P guidelines were used to present the literature. PubMed and MEDLINE were systematically searched up to 1st February 2021. A dataset containing predetermined primary and secondary outcomes was extracted.

**Results:**

Eighteen studies including 375 patients fulfilled our criteria, with mainly rectal and gynaecological cancer participants. Only three studies had a follow-up greater than two years. Six surgical interventions were identified. Mesh reconstruction and breast prosthesis were associated with low rates of small bowel obstruction (SBO), enterocutaneous fistulas and perineal hernia. Findings for myocutaneous flaps were similar however they were associated with high rates of perineal wound complications. Omentoplasty was found to have a high perineal wound infection rate (40%). Obstetric balloons were found to have the highest rates of perineal wound dehiscence and SBO. Silicone expanders effectively kept small bowel out of the pelvis though rates of pelvic collections remained high (20%).

**Conclusion:**

The morbidity associated with the empty pelvis remains considerable. Given the low-quality evidence with small patient numbers, strong conclusions in favour of a certain technique and comparing these interventions remains challenging.

**What does this paper add to the literature?**

Previous systematic reviews have included abdominoperineal resections (APR) and pelvic exenterations (PE) together in their analysis of patient morbidity relating to the ‘empty pelvis’, underestimating the complications from PE, given PE leaves a larger ‘empty pelvis’. This systematic review is the first to evaluate these surgical interventions exclusively following PE.

**INTRODUCTION:**

Pelvic exenteration (PE) is a radical procedure involving the resection of multiple pelvic viscera for primary and recurrent pelvic malignancies. The median 5-year overall survival for those with locally advanced and locally recurrent rectal cancers undergoing PE has been reported at 38% and 28% respectively1,2 and 40% for gynaecological cancers3. In the case of colorectal cancer, this compares to a 5-year survival <5% without resection4.

PE carries a high complication rate (up to 80%)5. A substantial proportion (up to 40%) of the morbidity after PE can be attributed to pelvic sepsis and perineal wound complications6, with the large pelvic cavity created being a major contributor. The sequalae that develop subsequent to the creation of this large pelvic cavity have been termed the ‘empty pelvis syndrome’7. This includes accumulation of fluid and migration of small bowel loops into the pelvis with the potential for pelvic abscess, perineal fluid discharge with perineal wound dehiscence and prolonged ileus or bowel obstruction. Additionally, entero-perineal and enterocutaneous fistulas (often arising from entero-enterostomy anastomoses and urine leaks from uretero-conduit anastomoses) can affect nearly 10% of patients undergoing PE and contribute significantly to the ‘empty pelvis syndrome’5.

In addition to the void created, there are two further aspects of the ‘empty pelvis syndrome’. The extensiveness of PE also creates large defects in the pelvic floor as well as the skin. Several surgical techniques have been employed that aim to address the ‘empty pelvis’ to prevent these complications including myocutaneous flaps (MCF), synthetic and biological meshes, omental flaps and other pelvis fillers, each with their own advantages and disadvantages. Each technique addresses different aspects of the ‘empty pelvis syndrome’. MCFs primarily aim to fill the skin defect with the associated muscle bulk providing some means of filling the ‘empty pelvis’, however, it can contribute its own morbidity (e.g., flap loss)8-9. The use of muscle-sparing flaps for the ‘empty pelvis’ are less frequently described with uncertain efficacy10. Mesh reconstruction replaces the pelvic floor with its reported benefits unclear. Reports include reduced long-term incidence of perineal hernia11, however, in the BioPEX randomised controlled trial (RCT)12 the use of biological mesh in extralevator APR was not found to reduce the rates of surgical and non-surgical complications compared to primary closure. The use of other pelvic fillers remains controversial, showing efficacy in case reports and small cohorts only13-14.

To date, there is no consensus on how effective each strategy mitigates the ‘empty pelvis syndrome’. Part of the challenge is the paucity and heterogeneity of PE cohorts. Many studies also combine the outcomes for PE and APR together15. The aim of this systematic review is to evaluate and compare the morbidity of surgical techniques designed to mitigate the ‘empty pelvis’ in an exclusive PE cohort.

**METHODS:**

**Search strategy:**

This systematic review was carried out in line with PRISMA-P guidelines. The protocol was prospectively registered with PROSPERO on 25th February 2021 (CRD42021239307). MEDLINE and PubMed were systematically searched up to 1st February 2021 (supplemental digital content 1). References lists of included articles were manually screened to identify additional papers. Table 1 demonstrates the eligibility criteria.

PE was defined as the complete en bloc resection of the rectum, genitourinary viscera, reproductive internal organs, regional lymph nodes, and peritoneum, with total PE (TPE) defined as complete visceral exenteration with two stomas with or without sacrectomy1,16. The definition of ‘empty pelvis syndrome’ varies. To capture all relevant studies, we defined ‘empty pelvis syndrome’ as a large defect/void that is generated following PE that predisposes a patient to a number of complications including pelvic abscess, collection, prolonged ileus, mechanical bowel obstruction and fistula or sinus formation due to the sequelae of fluid accumulation and migration of small bowel into the ‘empty pelvis’7,17,27,29.

# Study selection:

The titles, abstracts and full-texts were evaluated by two independent reviewers (YJ and MW). Studies that did not meet the eligibility criteria were excluded. Attempt to retrieve missing full-texts was made through consultation with medical librarians.

**Data extraction:**

A data abstraction table was created a priori in Microsoft Excel containing study characteristics, patient characteristics as well as predetermined variables related to the primary and secondary outcomes. Patient and study characteristics are presented in line with the IDEAL (Idea, Development, Exploration, Assessment, Long term monitoring) framework for 2A studies18.

**Outcomes:**

The **primary outcome** was the proportion of patients who developed complications specifically related to the ‘empty pelvis’. Six complications were specifically assessed:

1. *Pelvic abscess* (within 30 days of surgery)
2. *Small bowel obstruction* (within 90 days of surgery)
3. *Enterocutaneous fistula* (no time constraint)
4. *Perineal wound infection* (within 30 days of surgery)
5. *Perineal wound dehiscence* (within 30 days of surgery)
6. *Perineal hernia* (no time constraint)

In addition, combined perineal wound complications (total, minor and major) as well as overall morbidity were assessed.

**Secondary outcomes** included intervention specific complications, rate of re-operation and 30-day postoperative mortality. All outcomes were defined using previously published definitions8,30-33.

**Quality assessment:**

The quality of studies was assessed using the Newcastle-Ottawa scale (NOS)34. The scoring system was modified for studies without comparators by removing criteria concerning comparability, producing a score out of 6 (Supplemental Digital Content 2). For studies with comparators, six or more stars (out of 9) indicated high methodological quality. For studies without comparators, 5 or 6 stars (out of 6) indicated high methodological quality.

**RESULTS:**

**Literature search:**

After duplicates were removed, 1238 papers were identified. Two additional papers were identified through screening reference lists of cited studies. Following title and abstract screening, 1176 papers were excluded. The full text of the remaining 64 papers were reviewed and included/excluded according to the eligibility criteria. Full details are illustrated in the PRISMA flow diagram35 (Figure 1).

Eighteen papers comprising 375 participants were identified (published between 1999 and 2021). Studies were either retrospective cohorts (59%) or case series/reports (41%). Nine (50%) studies included 10 patients or less. Besides two small case series28,29, the median length of follow-up for each study was greater than six months (IQR = 23 months). Only three studies had a follow-up greater than two years16,19,24. The median NOS score for studies with comparators was 7 (range 5-9), and 6 (range 5-6) for studies without comparators implying the studies were of adequate quality. Sixty-nine percent of participants were treated for rectal cancer and 24.4% for gynaecological malignancies.

**Myocutaneous flap reconstruction:**

Ten studies, comprising 234 participants, were identified9-10,16-17,19-24. One hundred and thirty-seven patients (58.5%) were female with a mean age of 57.9 years (IQR 6 years). Where stated, 51.9% (108/208) were treated for recurrent malignancies with 60.7% (136/224) receiving neoadjuvant radiotherapy (neoRT).

*Characteristics of MCF reconstruction*

TPE was carried out in 75.5% of patients (111/147). VRAM was most common MCF (Table 2). Agreement on fascial preservation was apparent, however, disagreement was observed on preservation of the inferior attachment of the rectus abdominis20-21. There was variation between studies as to the surgical speciality performing the reconstruction, including surgical oncologists and plastic surgeons.

*Primary outcomes for MCF reconstruction*

MCF reconstruction was associated with relatively high rates of wound infection10,19-24 and dehiscence10,16,19-24, with mean pooled rates of 18.3% (30/164) and 23.4% (47/201) respectively (Table 3). There were high rates of minor and major perineal wound complications – 31.3% (42/134) and 16.3% (25/153) as well as high overall morbidity at 62.8% (59/94). Mean rates of pelvic abscess was 16.9% (14/83) 9-10,17,19-20,22. Additionally, rates of SBO9-10,17,20-22, fistula9-10,17,20,22-24 and perineal hernia23 were demonstrated at 2.2% (2/91), 7.5% (14/187) and 5.7% (5/87) respectively.

*Secondary outcomes for MCF reconstruction*

MCF reconstruction was associated with high rates of reoperation - 19.3% (11/57)10,16-17,19 though there was no 30-day mortality. An average of 4.6% (9/197) of the MCF cohort experienced complete flap loss with 6.1% (11/180) experiencing partial flap loss.

**Omental flaps:**

Only one study was identified26, comprising ten participants (8 males, 2 females) with a mean age of 63 years. Seven patients were treated for rectal cancer (5 primary, 2 recurrent) and three for prostate cancer with no participants receiving neoRT.

*Characteristics of omental flaps*

Eight (80%) participants underwent TPE. Following exenteration, the omentum was dissected from the transverse colon and greater curvature of the stomach with the harvested flap tunnelled in the retro-colic plane through the mesentery of the transverse colon and ileocaecum to the pelvic floor. This direct path provided sufficient length for the omentum to reach the pelvic cavity.

*Primary and secondary outcomes for omental flaps*

Four patients developed a wound infection with an overall morbidity rate of 80% (8/10). The supplementary morbidity was due to cases of prolonged ileus and urinary tract infections. No patient developed an abscess or any other significant complication.

**Mesh reconstruction:**

Two studies, comprising 12 participants undergoing TPE were identified7,25. A total of 66.7% (8/12) of participants were female with a mean age of 59.3 years and 75% (9/12) of patients were treated for recurrent disease with all but one patient receiving neoRT.

*Characteristics of mesh reconstruction*

All meshes were absorbable (Table 2). De-la-Noval et al.25 utilised a non-cross-linked porcine acellular dermal matrix for earlier integration into tissues, while Lee et al.7 used mesh composed of synthetic polymers due to its increased rigidity.

*Primary outcomes for mesh reconstruction*

Mesh reconstruction was associated with a 16.7% (2/12) risk of pelvic abscess and rates of wound infection and dehiscence were demonstrated at 8.3% (1/12). It was associated with a total and major perineal wound complication rate of 16.7% (2/12) and overall morbidity rate of 50% (6/12). No patients developed a SBO, fistula or perineal hernia7 (table 3).

*Secondary outcomes for mesh reconstruction*

No patients developed a mesh specific complication, and the mesh did not need to be removed in any case, yet rates of re-operation were high at 16.7% (2/12). There was no 30-day mortality.

**Breast prosthesis:**

Three studies (comprising 86 participants) were identified13,27-28. Where reported, 62.0% (36/58) were female, with a mean age of 58 years. A total of 52.4% (44/84) underwent treatment for recurrent disease. Only 21.4% (12/56) received neoRT11.

*Characteristics of breast prosthesis*

Only 11.6% (10/86) of patients underwent TPE. Two studies13,27 opted for the use of silicone breast prothesis with the other using saline filled prothesis28 (Table 2). Technique for the silicone prosthesis was similar - first measuring the volume of the ‘empty pelvis’ with saline and matching this to the prosthesis. In contrast, Van Le et al. opted for a one-size fits all approach (standard size of 300cc).

*Primary outcomes for breast prosthesis*

Breast prosthesis was associated with a 10.3% (6/58) risk of wound infection13,28. In addition, 13.3% (4/30)27-28 of participants developed a pelvic abscess (table 3). Strikingly, no patients experienced a wound dehiscence, SBO, fistula or perineal hernia.

*Secondary outcomes for breast prosthesis*

Three (3.5%) of the 86 patients required implant removal. However, these were all due to returns to theatre for anastomotic leaks. This reconstruction was associated with a relatively low re-operation rate of 5.8% (5/86)13,27-28 with no 30-day mortality.

**Obstetric balloons:**

One case series was identified29 including three patients treated for locally advanced rectal cancer, though details on age and gender were not provided. All patients received neoRT.

*Characteristics of obstetric balloons*

All patients underwent TPE. Following exenteration, the balloon was placed into the pelvis and filled with 500mls of saline. In the first patient, the balloon was deflated and removed on post-operative day 5, however, this patient developed subacute SBO. Therefore, in the subsequent patients the balloon was deflated over several days and removed on day 11.

*Primary and secondary outcomes for obstetric balloons*

In addition to the SBO described, the second patient experienced persistent perineal wound discharge with the wound healing over the following three weeks. The third patient developed a pelvic seroma and was managed conservatively. No other complications were described with no 30-day mortality, though follow-up was limited to three months. Follow-up CT imaging in the second and third patient demonstrated that small-bowel loops remained out of the pelvis.

**Silicone expanders:**

One case series was identified14 comprising 30 participants (26 women, 4 men) with a mean age of 52 years. All patients were treated for recurrent disease (20 gynaecological, eight colorectal and two sarcomas). Furthermore, 53.3% (16/30) of patients received neoRT.

*Characteristics of silicone expanders*

All patients underwent TPE. Following this, the device was placed on the pelvic floor with the filling tube externalised. The device was then filled with saline solution (300ml capacity). Where possible, the caecum was dissected and turned inferomedially and placed onto the device. On average, the device was removed 9.5 days after surgery (range 7-26). The device was emptied through the externalised tube and then tractioned and removed. During removal, the small bowel was seen dropping into the pelvis in one patient (removal on day 7). Post-operative CT imaging confirmed intestinal loops remained out of the pelvis in all other patients.

*Primary and secondary outcomes of silicone expanders*

One patient developed a SBO following device removal (in the patient whose small bowel dropped). This required additional surgery and replacement of the device. Pelvic abscess developed in 20% (6/30) of patients and one patient developed a fistula. There was no 30-day mortality.

**DISCUSSION:**

This systematic review identified six different interventions which all addressed certain aspects of the ‘empty pelvis syndrome’ to reduce the associated morbidity. In summary, mesh reconstruction and the placement of breast prosthesis into the pelvis were associated with some of the lowest rates of SBO, fistula and abscess formation without any reported additional morbidity. Findings for MCF reconstruction were similar although rates of perineal wound morbidity and re-operation were high. These findings are consistent with a systematic review by Buscail *et al36.* They concluded that although patients who underwent MCF reconstruction following APR had reduced total and major wound complications (compared to primary closure), in patients who underwent MCF reconstruction post PE, there was increased major and total perineal wound complications. This difference in morbidity in APR vs PE further emphasises the need for future studies to report these outcomes separately.

Omentoplasty was associated with zero cases of pelvic abscess but showed high rates of wound infection and overall morbidity. However, data were only provided by one paper and many variables were not reported (e.g., SBO, fistula). No intervention-specific complications were identified, however, omentum inflammation and infarct/necrosis of the omentum have been described in patients with rectal cancer37.

The obstetric balloon was shown to be effective in keeping small bowel loops out of the pelvis and in patients whose balloon was left in for longer, complications relating to the empty pelvis were not reported. The silicone expander was associated with low rates of SBO and fistulas without any additional morbidity, though rates of pelvic abscess remained high. These more novel techniques were only evaluated by one centre hence drawing comparisons with more traditional techniques remains difficult. The effectiveness of techniques that do not primarily fill the pelvis (i.e., MCF and mesh reconstruction) demonstrates that there are multiple different aspects of the ‘empty pelvis’ that can be addressed – broadening the options going forward.

The limitations of this study predominantly lie with the studies included which comprised small patient numbers with short follow-ups. Additionally, all but one study was retrospective carrying risks of selection and publication bias. Furthermore, these studies are in themselves difficult to interpret due to a lack of consistent definitions of morbidity and operation descriptors with heterogeneity in outcome reporting. Moreover, there was significant variation between studies in the types of cancers as well as the proportion of patients receiving neoRT. This is an important clinical parameter as neoRT increases perineal wound complications by 10-fold38. Patient comorbidities and additional complications were not reported, which may act as potential confounders. It is also unclear whether the magnitude of surgery varied with the reconstructive options employed for example, with larger more morbid procedures favouring MCFs. Statistical comparison between different techniques was felt to be inappropriate due to the paucity of events descried and the heterogeneity of data making strong conclusions in favour or against techniques difficult.

Despite our findings, the optimal approach in dealing with the ‘empty pelvis’ remains unclear. This systematic review has highlighted the need for more high-quality evidence reporting multicentre morbidity with tighter definitions on operative details, reconstruction technique, morbidity and confounders. The length of follow-up should also be longer to ensure long-term outcomes are captured.

Currently the ‘empty pelvis syndrome’ is defined by a collection of known associated complications. A more anatomical and dimension specific definition of the ‘empty pelvis’ may be utilised in the future. A technique has been described by Carboni *et al13.* who measured the volume of the ‘empty pelvis’ during surgery by filling it with saline, matching this to the size of their prothesis. Radiological assessment of the ‘empty pelvis’ with image evaluation after reconstruction would also be more reproducible. This has been shown by Kitano *et al39* where 3D models have been generated from CT imaging showing the positional relationship between the MCF and the residual contents of the abdomen and pelvis. The application of this technology would be useful for other pelvic ‘fillers’, particularly those that are often too small (e.g., omental flaps).

Novel methods in filling the ‘empty pelvis’ may be extrapolated from advances in non-pelvic sarcoma surgery which similarly results in large defects. One such technique includes a prosthesis made from 3D printing technology, that can accurately fill the defect as determined by preoperative imaging. One study suggests this to be an encouraging option for filling massive defects with promising clinical results40. More innovative options such as tissue engineering and regenerative medicine may also have the theoretical potential to fill the ‘empty pelvis’. Bio-scaffolds are being developed with promising preclinical results, though concerns remain regarding its use in an oncological setting due to the associated stem cells and growth factors41.

In summary, whilst mesh reconstruction, MCF reconstruction, omentoplasty and breast prosthesis all appeared to prevent the complications associated with the ‘empty pelvis syndrome’ in some way (relatively low rates of SBO, fistula formation and/or pelvic abscess), MCFs and omentoplasty appear to contribute significant perineal wound complications and overall morbidity. More high-quality evidence is required to enhance the understanding of how best to address the ‘empty pelvis’.

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**Figure 1**

Records identified through PubMed database search

(n = 1194)

Records identified through MEDLINE database search

(n = 981)

Records after duplications removed

(n = 1240)

Title and abstract screened

Full-text articles assessed for eligibility

(n = 64)

Studies included in qualitative synthesis

(n = 18)

Records excluded after title and abstract screen

(n = 1176)

Full-text articles excluded with reasons:

1. Wrong study design - e.g., reviews, protocols, statements, technique etc. (n = 13)
2. Wrong patient population – e.g., inclusion of abdominoperineal excisions (n = 16)
3. Wrong intervention – e.g., not addressing the empty pelvis (n = 8)
4. Full text not available (n= 4)
5. Multiple interventions in the study (n=5)

Records identified through manual cross-referencing

(n = 2)

***Figure 1 –*** *PRISMA flow diagram of the literature search, study selection and inclusion (with reasons for full-text exclusion).*

**Table 1** – The inclusion and exclusion criteria of this systematic review.

|  |  |
| --- | --- |
| **Inclusion criteria** | **Exclusion criteria** |
| Age ≥18, any gender | Patients undergoing more limited perineal resections (e.g., APR) |
| PE followed by some intervention targeted at filling the empty pelvis | Intervention not primarily aimed at filling the pelvis (e.g., vaginal reconstruction) |
| Surgery undertaken for malignancy | Surgery undertaken for benign disease |
| RCT’s**,** retrospective and prospective observational studies, case-control and cross-sectional studies, case series and case reports (No cut-off/requirement for patient numbers – i.e. n ≥1)  Studies with comparators will also be included. | Insufficient outcomes reported |
| Studies published in English language | Studies published in foreign language |

PE – pelvic exenteration, APER – abdominoperineal excision of rectum, RCT – randomised controlled trials.

**Table 2 –** Characteristics of myocutaneous flap, mesh and breast prosthesis studies presented using the IDEAL framework.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Patients**  **n**  **Type of PE**  **Indication** | **Surgical speciality** | **Output** | **Intervention** | **Method/**  **Design** | **Outcomes** |
| **Chokshi RJ9** | n = 17  TPE  Rectal & Gynae cancers | Single surgical oncologist. Assistance from plastics. | VRAM 15-20cm in length, 5-8cm in width. Fascial preservation – lower tension closure of rectus fascia. Flap rotated into pelvic defect. | VRAM flap | Retrospective  Cohort | Operative variables  Morbidity  Mortality |
| **Cibula D17** | n = 16  TPE  APE  PPE  Primary gynae cancers | - | MRAM harvested uni- or bilaterally - determined by size & shape of defect. Preservation of anterior fascia sheath. MRAM rotated 180° into the pelvis. | MRAM flap | Retrospective  Cohort | Surgical data  Post-op complications  Disease status |
| **Contedini F19** | n = 1  TPE  Primary anal cancer | General surgeon and urologist. | 22 X 12 cm flap (pedicle length 16cm). Tunnelled under the muscular plane into pelvic area to avoid kinking. | Anterolateral thigh flap + lotus petal | Case report | Post-op complications  Disease state |
| **Creagh TA16** | n = 37  TPE  Primary & recurrent cancers | Same colorectal surgeon – input from gynae and urology teams if necessary. | Flap raised sparing the rectus fascia (lateral and medial row perforators included). Flap inset with a double-barrelled technique. | VRAM flap | Retrospective  Cohort | Operative variables  Complications  Tumour variables |
| **Ishikawa S10** | n = 3  TPE  Recurrent gynae cancer | - | Flap size 14X6 to 16X8cm. Flaps raised from lateral side above gluteal maximus fascia. Edges de-epithelialised and flap transposed into pelvic defect. | Bilateral gluteal flap | Case series | Complications |
| **Jacombs AS20** | n = 39  TPE  Primary and recurrent rectal cancer | Urological, vascular, orthopaedic, plastic and reconstructive surgeons. (one principal surgeon) | Unilateral flap raised. VRAM turned medially inwards and rotated through pelvis into perineal defect. Inferior attachment of rectus abdominis persevered. | VRAM/gracilis  /gluteal | Retrospective  Cohort | Operative data  Postoperative data (including complications) |
| **Jeon H21** | n = 9  APE  PPE  Rectal & Gynae cancers | - | Flap size 5X12 cm up to 8X13 cm. Flap elevated vertically off posterior sheath and separated from all attachments. Delivered into perineum through a tunnel beneath pubic ramus. | VRAM flap | Retrospective  Cohort | Treatment characteristics  Surgical outcomes & complications |
| **Sasaki K22** | n = 7  TPE  Recurrent rectal cancer | Gastroenterological surgeons (Exenteration and reconstruction). | Incision on femoral skin over gracilis muscle. Gracilis muscle transected at the distal end and rotated towards perineal wound. | Bilateral gracilis flap | Case series | Operative data  Surgical outcomes and complications |
| **van Ramshorst GH23** | n = 87  Primary and recurrent pelvic cancers | Tertiary referral centre | - | VRAM flap | Retrospective  Cohort | Flap related complications (short & long term)  Readmission  Mortality  Quality of life |
| **Wong S24** | n = 18  TPE  PPE  Primary and recurrent pelvic cancers | One oncologic surgeon and one plastic surgeon | Flap elevated and tunnelled under the rectus femoris muscle and subcutaneously in the medial thigh to reach the perineal area. | Anterolateral thigh flap (vastus lateralis muscle) | NS | Surgical outcomes  Complications  Disease state |
| **De-la-Noval BD25** | n = 2  TPE  Recurrent gynae cancer | - | Non-cross-linked porcine acellular dermal matrix fixed with 2/0 polypropylene suture to reduce seroma formation. | Biological mesh | Case series | Complications  Disease status |
| **Lee P7** | n = 10  TPE  Primary and recurrent pelvic cancer | - | Mesh trimmed with scissors and moulded to pelvic contours and fashioned as a cone. Positioned above the pubic symphysis anteriorly and inferior to sacral promontory posteriorly. Anchoring stitches not used. | Degradable synthetic mesh (degrades within 6 months). | Prospective  Cohort | Postoperative complications |
| **Carboni F13** | n = 56  TPE  PPE  Primary and recurrent pelvic cancer | - | Empty pelvis filled with saline to measure its volume and determine prosthesis size (added 50cm3 in females). Covered by pseudo-capsule to avoid adhesions. Drains placed in pelvis prior to inserting prosthesis. Prosthesis left in situ. | Silicone anatomical shaped breast prosthesis | Retrospective  Cohort | Perioperative features  Postoperative mortality and morbidity |
| **Valle M27** | n = 28  TPE  PPE  Primary and recurrent pelvic cancer | - | Volume of residual cavity measure using sterile solution to quantify size of prosthesis. Volume augmented by 50cm3 in females. Silicone implants rotated by 180°. Drains placed in pelvis before implants placed. Left in situ unless patients underwent recanalisation. | Silicone anatomical shaped breast prosthesis | Prospective  Cohort | Early and delayed complications |
| **Van Le L28** | n = 2  TPE  Gynae cancer | - | 300cc saline implant filled with normal saline via accompanying filling tube, cap closed, and implant fitted into pelvic cavity. | 300cc saline filled silicone elastomer breast prosthesis | Case series | Postoperative complications |

TPE – total pelvic exenteration, APE – anterior pelvic exenteration, PPE – posterior pelvic exenteration. VRAM – ventral rectus abdominis myocutaneous flap. MRAM – modified rectus abdominis myoperitoneal flap. NS - not stated.

**Table 3** - Primary outcomes of the myocutaneous flap reconstruction, mesh reconstruction and breast prosthesis studies.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **I** | **Wound infection**  **n (%)** | **Wound dehiscence**  **n (%)** | **SBO**  **n (%)** | **Fistula**  **n (%)** | **Pelvic abscess**  **n (%)** | **Perineal hernia**  **n (%)** | **Perineal wound complications** | | |
| **Total**  **n (%)** | **Minor**  **n (%)** | **Major**  **n (%)** |
| **Chokshi RJ9** | F | - | - | 1 (6) | 3 (18) | 8 (47) | - | - | - | - |
| **Cibula D17** | F | - | - | 1 (6) | 0 (0) | 0 (0) | - | 0 (0) | - | - |
| **Contedini F19** | F | 0 (0) | 0 (0) | - | - | 0 (0) | - | - | - | 0 (0) |
| **Creagh TA16** | F | - | 7 (19) | - | - | - | - | - | 7 (19) | 6 (16) |
| **Ishikawa S10** | F | 0 (0) | 1 (33.3) | 0 (0) | 0 (0) | 0 (0) | - | 1 (33.3) | 1 (33.3) | 0 (0) |
| **Jacombs AS20** | F | 12 (30.8) | 17 (43.6) | 0 (0) | 2 (5.1) | 5 (12.8) | - | - | - | - |
| **Jeon H21** | F | 1 (11) | 1 (11) | 0 (0) | - | - | - | - | - | - |
| **Sasaki K22** | F | 1 (14.3) | 1 (14.3) | 0 (0) | 0 (0) | 1 (14.3) | - | 2 (28.6) | 1 (14.3) | 1 (14.3) |
| **van Ramshorst GH23** | F | 15 (17) | 14 (16) | - | 8 (9) | - | 5 (6) | - | 33 (38) | 15 (17) |
| **Wong S24** | F | 1 (6) | 6 (33) | - | 1 (6) | - | - | - | - | 3 (17) |
| **De-la-Noval BD25** | M | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1 (50) | - | 1 (50) | 0 (0) | 1 (50) |
| **Lee P7** | M | 1 (10) | 1 (10) | 0 (0) | 0 (0) | 1 (10) | 0 (0) | 1 (10) | 0 (0) | 1 (10) |
| **Carboni F13** | B | 6 (10.7) | 0 (0) | 0 (0) | 0 (0) | - | 0 (0) | - | - | - |
| **Valle M27** | B | - | - | 0 (0) | 0 (0) | 4 (15) | 0 (0) | - | - | - |
| **Van Le L28** | B | 0 (0) | 0 (0) | - | - | 0 (0) | - | - | - | - |

I – intervention. F – myocutaneous flap reconstruction. M – mesh reconstruction, B – breast prosthesis. SBO – small bowel obstruction.