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Original article

Persistent residual contamination in endoscope channels; a fluorescence epimicroscopy study

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Short title: Persistent contamination in luminal endoscopes

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# In brief

This study used fluorescence epimicroscopy to examine working channels from endoscopes, and found considerable amounts of protein and biofilm after cleaning. Calls for sustained precautions and efforts for improved methods for the reprocessing of nonautoclavable, reusable surgical instruments are important.

**Background and study aims:** The increasing demand for endoscopic procedures poses new contamination challenges, given developing antimicrobial resistance worldwide and potential viral or prion diseases in populations at risk. We examined working channels from reusable luminal endoscopes used in recent years.

**Methods:** Very sensitive fluorescence epimicroscopy was used to examine working channels from 6 decommissioned and 6 factory-new channels, as received, or following spiking and washing in the laboratory.

**Results:** After a single contamination and wash test cycle, new channels retained approximately 75 pg/mm2 of proteins; through 7 subsequent cycles residual proteins fluctuated between 25 and 75 pg/mm2. Decommissioned channels harbored 1–4 µg of proteins each, except in one gastroscope (33 µg), including up to 2% amyloid proteins except in one gastroscope and one sigmoidoscope (with over 80%); lumens showed wearing with established abraded biofilms in 3 cases. After spiking with scrapie-infected blood components and washing, residual protein levels in new channels varied following standard (17.23 pg/mm2), duplicated (2.39 pg/mm2) or extended (11.3 pg/mm2) washing; no changes were measured among the long-established contamination in old channels.

**Conclusions:** Our observations suggest that wear effects in endoscope lumens may contribute to the adsorption of proteins, thus facilitating retention and survival of bacteria. As demonstrated by recent outbreaks worldwide despite recommended reprocessing, the development of antimicrobial-resistant bacterial strains, and the estimated prevalence of variant Creutzfeldt–Jakob disease (vCJD) in the UK particularly, combined with increasing demand for endoscopic procedures, call for sustained precautions and improved methods for the reprocessing of non-autoclavable, reusable surgical instruments.

# Introduction

Endoscopic interventions are common worldwide, ranging from simple observations of nonsterile body cavities to tissue sampling and more complex and invasive procedures such as endoscopic retrograde cholangiopancreatography (ERCP). Outbreaks of various antibiotic-resistant bacterial strains have been reported, associated with the use of ERCP duodenoscopes [1–4], gastroscopes [5], cystoscopes [6], or ureteroscopes [7]. Flexible luminal endoscopes are complex, fragile, and expensive instruments. They are used repeatedly with a relatively rapid turnaround, and present various reprocessing challenges because of their complexity and their incompatibility with heat sterilization, leading to reliance on material-compatible chemical or alternative treatments. While luminal flexible endoscopes may be refurbished and parts, including the various channels, may be replaced at a significant cost, high throughput within demanding endoscopy units prevents systematic inspection before each use. Current methods for assessing endoscope cleanliness rely on sufficient recovery after swabbing or flushing, with an inherent effect on sensitivity [8]. Bearing in mind these limitations, reported findings from such tests demonstrate that endoscopes remain significantly contaminated even after recommended reprocessing procedures [9,10].

Flexible endoscopes are cleaned according to the manufacturers’ recommendations, and there is a thriving market for specifically designed cleaning chemical methods and automated endoscope reprocessors. The Spaulding classification, which originated in the 1960s and originally considered endoscopes as semicritical devices, is increasingly challenged by the complexity of modern instruments and endoscopic interventions [11]. The adsorption of patient tissue proteins and potentially embedded bacterial, viral, or prion contamination in endoscope lumens may have significant implications. Proteinaceous deposits provide a favorable background for microbial colonization and biofilm formation, and further increase the risk of inadequate disinfection/sterilization [12]. Chemical and bacterial residues may induce toxic reactions or produce health-threatening infections in immunocompromised patients; there is also an increasing risk of transmission of antimicrobial-resistant strains [1–7]. Reported iatrogenic infections through instrumentation are often attributed to equipment failure, poor reprocessing protocol, or negligence [13–15], though endoscopes involved in several recent outbreaks were reprocessed in accordance with guidelines. The potential extent of subclinical cross-contaminations worldwide remains unknown, as some patients may remain asymptomatic [1,3,16].

The issues with bacterial contamination in endoscopes are well known and have been the focus of a number of studies [17–20]. The identification in the 1980s of the misfolded prion protein (PrPSc) as the most likely infectious agent of transmissible spongiform encephalopathies (TSEs) [21] led to a number of new concerns [22]. Transmissible encephalopathies are invariably fatal neurological diseases. Human TSEs identified so far include kuru, fatal familial insomnia, Gerstmann–Sträussler–Scheinker syndrome, and the sporadic and variant forms of Creutzfeldt–Jakob disease (sCJD and vCJD, respectively). Pathogenic prions (PrPSc) are amyloid, protease-resistant proteins capable of aggregating in the central nervous system, leading to fatal neurodegeneration. Worldwide, sporadic CJD has an estimated incidence of approximately 1 per million in the general population. However, recent prevalence studies in the British population based on the analysis of lymphoid tissues suggest that 1 in 2000 people are asymptomatic carriers of vCJD [23], possibly following exposure to bovine spongiform encephalopathy (BSE)-infected meat during the peak of the BSE crisis in the 1990s. There is a concern that vCJD in the least susceptible individuals may present a similarly lengthy incubation period to that observed in other TSEs (up to 50 years for kuru). Although these patients may not develop symptoms during their lifetime, the wide tissue distribution of potential infectivity seen in vCJD, including in blood, implies a risk of transmission through surgical procedures. Consequently in the UK, despite the claims from manufacturers of decontamination products, endoscopes, and other reusable instruments that come into contact with potentially infectious tissues from identified vCJD patients, or patients deemed at increased risk of incubating the disease, are subsequently removed from general use at a significant cost.

The particular issues relating to vCJD in the UK have prompted a number of studies on the actual efficacy of reprocessing regimens against proteinaceous contamination, to obtain a better understanding of current potential shortcomings, particularly in heat-labile endoscopes. In the present study, working channels from various types of decommissioned endoscopes which had been in service until recently, were extracted to identify and quantify potential residual contamination present in the lumen, particularly biofilms and protein deposits including amyloid aggregates characteristic of some PrPSc-infected tissues [24]. Using new and used endoscope working channels, the efficacy of extended or duplicated enzymatic treatment was also assessed, since these have been proposed as simple alternatives to tackle the issue of hard-to-remove hydrophobic prions in endoscopes used in known vCJD patients. The findings are discussed globally in terms of potential risks that may be associated with endoscopic procedures.

# Methods

## Sourcing of used endoscopes and new channels

Decommissioned and fully reprocessed endoscopes used for screening, diagnostic, and other interventions on the general population were kindly given to us by hospital-based endoscopy units in UK. This study focused on four gastroscopes, one colonoscope and one sigmoscope (**Table 1**). Six new working channels of the same type, kindly given by a global manufacturer, were also used in this study.

## Staining and microscopy

Episcopic differential interference contrast combined with epifluorescence (EDIC-EF) microscopy (Best Scientific, Swindon, UK) is a very sensitive technique for the rapid qualitative and quantitative assessment of microcontamination on surfaces [25]. Proteinaceous deposits on endoscope accessories and inside channel lumens were detected using SYPRO Ruby (Molecular Probes, Eugene, Oregon, USA). Thioflavin T (Sigma-Aldrich, Saint Louis, MO) was added in dual-staining experiments to detect amyloid aggregates as described elsewhere [24]. The staining protocol for endoscope working channels was as described before [26]. Staining was quantified from 10 representative fields of view for each channel, examined using Image-Pro software (Media Cybernetics, Silver Spring, Maryland, USA).

## Adsorption of proteins in new channels and washing protocol

A standard proteinaceous test soil (Edinburgh test soil; Medisafe; Bishops Stortford, UK) was aspirated through 3 new channels using sealed syringes, the excess was flushed out, and the adsorbed soil left in place according to the manufacturer’s instruction prior to washing.

Manual washing was performed using a common enzymatic cleaner which had previously given comparatively good results in our hands in terms of protein removal (Enzol; Johnson & Johnson, Maidenhead, UK). Channels were immersed for 5 minutes and the enzymatic solution was flushed slowly through the lumen using a syringe to ensure contact between the chemical and the surface and the absence of trapped air. Brushes were applied while the channels were immersed, following the manufacturer’s recommendations [26]. The same channels were then subjected to several identical contamination–decontamination cycles and a section removed and stained each time.

## Enhanced washing for prion-contaminated channels

The effect of extended cycles (doubled duration of enzymatic soaking) or doubled washing cycles (2 × 5-min soaking in fresh solution each time) was compared with that of a standard manual washing (described above) on new and used channels contaminated with partly reconstituted sheep blood infected with scrapie, a TSE affecting sheep. (Infectious plasma and buffy coat [which contains white blood cells] isolated by blood fractionation were a kind gift from Dr Olivier Andréoletti, Institut National de la Recherche Agronomique, UMR 1225, Toulouse, France).

The plasma and buffy coat pool was aspirated through the channels as described above, excess flushed out, and channels reprocessed with enzymatic cleaner and brushes within 30 minutes to mimic an endoscopy unit with a “next door” reprocessing facility. Brushes were applied only during the first soak as we had previously observed that brushing contributed to the spreading of residual microcontamination in wet channels, adversely affecting results [26].

## Statistics

All data were expressed as mean ± SEM from at least three separate experiments. The protein adsorption profiles in new channels during the first 8 cycles and the effect of various reprocessing regimens for new and old channels spiked with prion-infected tissues were analyzed using a linear mixed model, with replicate channels selected as random effect and the number of contamination–wash cycles or reprocessing regimen selected as fixed effect, respectively. A value of *P* ≤ 0.05 was considered significant. SPSS software was used

# Results

## Early adsorption of proteinaceous contamination in new channels

From the first cycle in new channels we observed residual microcontamination in the form of spots (**Fig. 1a,b**) and longitudinal smears (**Fig. 1c,d**) along the channels, possibly due to the spreading action of brushes on larger residues, as we reported previously [26]. For a given number of cycles, there were no significant differences between replicates. Following the initial increase (*P* = 0.002 when compared with clean new channel), levels of residual proteins measured on the luminal surface remained within the same range and fluctuated around what we termed a “basal level of microcontamination” of 25–75 pg/mm2 (*P* = 0.156; **Fig. 2**).

This equates to 0.1–0.9 µg of proteins per meter (for channel diameters ranging from 2.0 to 6.0 mm) adsorbed on the luminal surface early in the endoscope’s life. This is not visible by current visual inspection methods and below the level of detection of test kits currently available on the market (which measure only recovered proteins and remain above the microgram range).

## Proteinaceous and bacterial contamination in channels from decommissioned endoscopes

Channels extracted from decommissioned endoscopes harbored residual proteinaceous microcontamination including some amyloid aggregates (**Fig. 3**). Protein residues remained under 500 pg/mm2 (values were equivalent to 1–4 µg of proteins per channel), except in one channel which harbored 3.59 ± 0.88 ng/mm2 (equivalent to almost 33 µg of residual proteins for the whole channel).

The amount of amyloid aggregates stained by thioflavin T represented 80% of the total contamination detected in two channels (from a gastroscope and a sigmoidoscope), up to 191.0 ± 75.3 pg/mm2 (equivalent to 1.2–2.5 µg of residual amyloid proteins per channel, based on common channel sizes). In contrast amyloid aggregates were only up to 2% of total proteins in the other 4 channels reported here. All 6 clinically used channels presented longitudinal wearing and abrasion marks on their luminal surfaces, within which residual proteinaceous microcontamination could be found (**Fig. 4a–c**). Some biofilms were observed, and some had clear abrasion marks running longitudinally through them, suggesting that these biofilms had been implanted for some time and survived at least one subsequent use/reprocessing cycle (**Fig. 4d–h**).

## Limited improvement from extended or duplicated enzymatic treatments on channels spiked with prion-infected blood components

Isolated spots of proteins were occasionally found on the luminal surface of new channels. Since our protocol prevents exogenous proteins from entering the channel before the stain, this finding suggests that such small amounts of proteins may be present within new channels immediately after the manufacturing process. No amyloid proteins were detected in new channels.

For comparison, we used sections of a working channel from a single colonoscope (termed here “old channel”), which already harbored amyloid and other protein residues (17.9 ± 4.9 pg/mm2 and 13.3 ± 6.5 pg/mm2, respectively).

After contamination with prion-infected blood components, 91.9 ± 19.0 ng/mm2 of protein were found to be adsorbed in new channels (**Fig. 5a,b**) and 172.4 ± 18.3 ng/mm2 in old channels (**Fig. 5c,d**), which corresponded to near-saturation under our EDIC-EF microscopy imaging. In spiked new channels, amyloid proteins were not detected among the fresh contamination consisting exclusively of the prion-infected blood fractions. In old channels which previously harbored historical residues, measurable amyloid aggregates amounted to 1.0 ± 0.6 pg/mm2.

After standard wash, residual amyloid and other proteins in new channels amounted to 6.77 ± 1.2 pg/mm2 and 17.2 ± 5.4 pg/mm2 respectively, which corresponded to a 103 to 104 reduction in total proteins when compared with the positive (spiked) control, depending on experiments. In used channel sections, residual amyloid represented 20.3 ± 7.55 pg/mm2 and other proteins 15.3 ± 7.48 pg/mm2. These figures demonstrate the relative efficacy of the process, though residual levels in old channel sections were similar to the initial “basal levels of microcontamination” (from previous clinical use).

Differences from reprocessing treatments were visible after one cycle in new channels. Repeating the enzymatic immersion alone with a fresh enzymatic solution led to a further reduction in total proteins (2.38 ± 1.8 pg/mm2; *P* = 0.029) when compared with the standard wash; however residual amounts of amyloid proteins were similar. Extending the enzymatic immersion phase of a single wash (with brushing) appeared to have adverse consequences. Levels of residual total proteins tended to increase (although not significantly due to variations between experiments), and levels of residual amyloid were significantly raised. In old channels, duplicated or extended reprocessing did not improve the outcome, as residual contamination (amyloid and total proteins) was only reduced back to “basal” levels.

# Discussion

We have previously reported that proteins adsorb readily inside new endoscope channels and partly resist enzymatic immersion, brushing, and flushing. Using EDIC-EF, residual proteinaceous microcontamination can be measured on the luminal surface of various new polytetrafluoroethylene (PTFE) endoscope biopsy channels after a single contamination–wash cycle [26]. Here we repeated the same cycles over several days to simulate a relatively low frequency of use (maximum 2 cycles per day) in identical new and intact biopsy channels.

 The source of proteins occasionally found in minute amounts in new, unused biopsy channels is unclear, though the manufacturing process is expected to limit such contamination. These observations demonstrate the need for full reprocessing of new endoscopes in clinical settings before use on patients. We measured here how repeating the same cycle in new channels, using a comparatively good enzymatic cleaner and strictly controlled parameters, led to the accumulation of proteins. The protein accumulation at this early stage remained under 1 µg per channel, which is below the sensitivity of detection kits used in clinical settings, and appeared to fluctuate around a “basal level of microcontamination,” with no significant changes during at least the first 8 cycles. This suggests that each new cycle allows the spreading of minute amounts of microcontamination against which the enzymatic treatment with brushes is partly ineffective [26]. Consequently the amount of residual soil in various areas may fluctuate over time. While there is a trend towards centralization of reprocessing facilities, the impact of delay between contamination and reprocessing was not evaluated here. We observed retained moisture in endoscope lumens in the form of microdroplets. The potential impact of this on soil adsorption remains to be examined, though it is likely to facilitate bacterial growth.

We also observed how the wearing of ageing biopsy channels, possibly due to surgical accessories, may contribute to increasing the adsorption of proteins in endoscopes used in busy clinical settings. The decommissioned endoscopes that we obtained had been used for several months in a general patient population until recently, and can therefore be considered to be representative of current instruments.Our observations suggest that soil will aggregate and become partially degraded or displaced, either during the wash phase or subsequent use in a patient. The unavoidable wearing of luminal surfaces is also likely to facilitate the adsorption of tissues, which may partly account for the higher levels of residual proteins measured in older channels from decommissioned endoscopes. The potential risk associated with these protein residues remains unclear. Levels of toxicity to patients will depend on the amounts and nature of molecules liable to be transferred during various procedures. Proteinaceous deposits provide a favorable ground for the embedding of micro-organisms and development of biofilms, potentially impairing the action of chemical sterilization. The potential proximity of different bacterial strains within these deposits also offers opportunities for gene transfer [27,28].

Our observations bring further evidence relating to the global concern of cross-contamination through heat-labile reusable surgical instruments such as endoscopes. The residual protein amounts directly measured in this study are below the detection threshold of current commercial methods, and therefore unlikely to give a positive result through swabbing. The evidence suggesting that pathological prions alone are capable of transmitting TSEs has led to a progressive discontinuation in the use of potential protein fixatives, such as alcohol or glutaraldehyde, in some countries where vCJD is of particular concern [29,30]. Tests to detect bacterial colonization rely on the recovery of representative samples. Established biofilms such as those we observed might not always provide adequate samples through swabbing or flushing techniques currently used in clinical settings [8,31]. Bacterial components such as endotoxins may become adsorbed similarly to proteins and escape detection. In this study we did not try to identify individual bacteria, nor did we evaluate the potential for bacterial transfer and re-implantation through endoscopes and accessories such as forceps. Clinically significant cross-infections seem to be rare events, although various patient experiences or confusing clinical history may contribute to under-reporting [32]. Issues may arise when cross-contaminations involve particularly susceptible patients and/or pathogenic strains, leading to more serious (and visible) outbreaks [1,3,4,16]. Encouraging patients to report even minor complications might lead to early warnings, and prevent major occurrences provided appropriate corrective actions are taken. The potential risk remains to be addressed, as antibiotic resistance is spreading, and endoscope channels may offer one perfect ground for the exchange of resistance genes between bacterial species, contributing to antimicrobial resistance [1, 2].

Our dual staining demonstrates that amyloid proteins such as pathogenic prions are among the most difficult to displace or degrade. Partly reconstituted blood (plasma and buffy coat, with most red blood cells being absent) from scrapie-infected sheep proved a useful indicator for comparing the cleaning efficacy against total proteins and more specifically amyloid proteins. The presence of PrPSc and the infectivity of this material has been confirmed in other studies [33]; thus we considered it to be a representative soil for our purpose.

Our failure to detect any thioflavin-positive signal in new channels freshly contaminated with tissues known to contain prions may be due to the proportion of prions within these blood fractions being too low, or to hydrophobic prions being embedded in the relatively high quantity of other molecules consisting principally of proteins and lipids. We have previously reported the difficulty of detecting amyloid aggregates in lipid-rich tissues such as brain. This prompted us to add the surfactant Tween 20 to brain homogenates, which helped in separating lipids from protein aggregates, thus improving significantly our limit of detection of PrPSc in infected brain [24]. Our observations suggest similar issues exist when trying to detect prions in blood, and may have implications in the development of rapid blood tests for prion diseases.

In old channels, the presence of amyloid deposits in a sufficient amount to provide a signal detectable among the significantly larger, more recent contamination demonstrates how hydrophobic amyloid proteins are the most difficult to remove and represent the majority of historical residues adsorbed on old, worn surfaces.

With currently available assays it remains difficult to assess the potential risk of iatrogenic vCJD transmission via endoscopes [34]. While the presence of amyloid aggregates does not imply the presence of infectivity in these tissues, prions are known to remain infectious for months and carriers may remain asymptomatic for decades. Identified cases of iatrogenic CJD resulted from direct contact with CJD-infected or vCJD-infected surfaces or tissues identified to be at high risk of transmission. It is conceivable that infectious prions present in the blood of an asymptomatic vCJD carrier may be adsorbed with other proteins onto the outer and luminal surfaces of an endoscope. Transmission of vCJD via a flexible endoscope would require the detachment of prions from the surface of the instrument, absorption through mucosal layers, migration to the lymphoreticular system, and further disease progression following the currently understood pathophysiology of vCJD. The examination of endoscopes used on identified vCJD carriers may provide a better understanding of the potential associated risks. While there is increasing evidence of the potential for bacterial cross-infection through endoscopy, confirming the presence of vCJD infectivity in an endoscope, or in any other reusable instruments, requires the development of adapted and suitably sensitive assays. Iatrogenic transmission of vCJD through endoscopy has not been reported to date.

The growing number of endoscopic procedures increases the demand on staff and facilities, and on usage of individual endoscopes which remain expensive to buy or maintain [4,35]. Reprocessing regimens are mostly based on the recommendations of the manufacturers of endoscopes, automated endoscope reprocessors, and reprocessing chemicals. End-users are likely to welcome promises of regimens that are validated (i.e., giving acceptable results based on current standard tests), potentially faster, and thus cost-saving. The action of chemicals against the most difficult contaminants such as prions lacks independent certification. Our results suggest it is unlikely that more of the same treatment will remove well-established biofilms and proteinaceous microdeposits adsorbed along wear marks on the luminal surfaces of channels. Where major infection issues are identified, not only will procedures need to be reviewed but existing equipment may need to be refurbished or replaced to eliminate the risk of contamination from “historical residues” [35].

We examined the early adsorption of proteins only in one particular type of channel from a unique source. It is possible that different materials will have different adsorption characteristics, though in our experience most materials currently used in the manufacturing of reusable instruments are prone to protein adsorption. Our examination of clinically used channels was also limited to a small number of endoscopes from the south of England at their end of life, because our method presently requires the removal of the biopsy channel. The development of adapted, sensitive and accessible technologies for routine examination of channel lumens in situ, thus avoiding the issues of limited sample recovery, would provide end-users with better monitoring of their reprocessing regimens.

New technologies are being developed to bridge the gap between current capabilities in clinical settings and the potential threats associated with residual microcontamination. Given the ever-increasing demand on endoscopy clinics and the expansion of antimicrobial-resistant bacterial strains, new decontamination technologies are likely to have a key role in future healthcare.

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*Competing interests:* R. C. Hervé and C. W. Keevil declared no conflicts of interest or financial interest.

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**Fig. 1**   Representative pictures of residual protein contamination of the luminal surface of endoscope working channels observed under epifluorescence microscopy with SYPRO Ruby staining. Proteins appeared as: **a, b**  isolated aggregates; or **c,d**  smears along the luminal surface of the channel. Bars are 100 μm.

**Fig. 2**   Chronological profile of residual proteins adsorbed in new endoscope working channels artificially contaminated with Edinburgh soil prior to rinsing and enzymatic washing without delay. Data show means ± standard error of the mean (SEM) from three channel lumens examined in at least 10 different locations each, up to 8 contamination–washing cycles.

**Fig. 3**   Profiles of residual proteins adsorbed in endoscope working channels recovered from decommissioned endoscopes. Data show mean ± SEM amyloid (blue bars) and other proteins (amber bars) for each channel lumen examined in over 20 different locations along the channel. The upper panel shows the data as ng/mm2 and the lower panel shows the same data as pg/mm2 but is truncated at an upper value of 25.0 pg/mm2. (+BF) indicates biofilms were observed in those channels

**Fig. 4**   Merged epifluorescence and bright light micrographs of the lumens of working channels of decommissioned endoscope. **a–c**  Proteins stained orange by SYPRO Ruby. **b**  Some amyloid aggregates stained blue by thioflavin. **c–i**  The worn luminal surface of various working channels. **d–h**  Partly abraded biofilms stained by SYPRO Ruby. Bars are 100 μm.

**Fig. 5**   Comparison of contamination and residual adsorption profiles between: **a,b**  new endoscope working channels, and **c,d**  sections of a working channel recovered from a decommissioned colonoscope (4 separate experiments, channel lumens examined in at least 10 different locations each). Data show mean ± SEM amyloid (blue bars) and other proteins (amber bars) before (Neg) and after (Pos) contamination with scrapie-infected blood components, and following standard enzymatic manual wash with brushing (1x), double enzymatic wash with brushing during the first wash (2x), or doubled immersion time in a single wash with brushing (xl). The left-hand panels show the data as ng/mm2 and the right-hand panels show the same data as pg/mm2 but truncated at upper values of 55 pg/mm2 (new channel) and 100 pg/mm2 (old channel). \*, significant (*P* ≤ 0.05) decrease of same variable following alternative treatment (2x) when compared with single standard wash (1x); †: significant (*P* ≤ 0.05) increase of same variable following alternative treatment when compared with single standard wash (1x). All treatments were significantly successful (*P* ≤ 0.001) when comparing residual total proteins with the positive control (not shown on the graphs).

**Table 1**   Persistent residual contamination in endoscope channels. Biopsy channels were recovered from 6 decommissioned endoscopes after clinical use on the general population (i.e not on identified vCJD patients). All had been used and reprocessed several hundred times. There had been no identified cross-infection cases.

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| Endoscope no. | Type | Working channel dimensions, mm |
| 1 | GIF-PQ20 | 2.8 × 1030 |
| 2 | PCF-240S | 3.2 × 620 |
| 3 | CF-240AL | 3.2 × 1680 |
| 4 | GIF-XT30 | 2.8 × 1030 |
| 5 | GIF-Q40 | 2.8 × 1030 |
| 6 | GIF-XT30 | 2.8 × 1030 |