SusQI project report

Project Title: **A Holistic Approach to a Green and Sustainable Laparoscopic Appendicectomy**	Date of Report: Project completed as part of the Green Surgery competition, 26/04/2021 – 07/07/2021.

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Abstract

Aims: To reduce the carbon footprint of laparoscopic appendicectomy procedures by

1. streamlining the surgical process, reducing equipment consumption, and
2. exploring the Retractor for Abdominal Insufflation-less Surgery (RAIS) surgical device.

Method:

1. Process mapping identified key interventions including; A "Green" single equipment tray reducing instrument use from 119 to 49 items per operation; Reusable surgical drapes and gowns, gallipots, kidney dishes; correct waste triage; and
2. use of a RAIS device.

All interventions were tested in a real-time cadaveric study, with triple bottom line savings calculated.

Results: An estimated 417.4kgCO_2e reduction was achieved, 321kgCO_2e of which were attributable to avoided insufflator gas use. A conservative estimate of 50% applicability for the RAIS yields savings of 108.9 Tonnes CO_2e per year based on an average of 522 appendicectomies taking place in LTHT. Standard clinical and packaging waste was reduced by 86% and 64% respectively. With 80% applicability, green equipment trays could reduce sterilisation costs by £9,567 and 740kg CO_2e annually for this single operation. While RAIS slightly increases sterilisation requirements, this is offset substantially by reduced procurement cost. The cost of the device is recuperated after fewer than 10 uses. Non-RAIS, immediately implementable equipment changes saved an estimated 6.47kgCO_2e per procedure. With 80% applicability, Trust savings of 2,702kgCO_2e can be achieved.

Conclusions: We demonstrated the potential of interventions that can be applied both immediately into NHS practice and additionally with innovative new surgical approaches like Gas Insufflation-less Laparoscopic Surgery (GILLS), using the RAIS device, to enhance sustainable approaches in the global surgical community; highlighting the potential to transfer resource-efficient processes into major financial and environmental savings.

The Centre for Sustainable Healthcare would like to acknowledge the Green Surgery Challenge gold sponsors NIHR Surgical MedTech Co-operative and Elemental Healthcare; as well as our partners NIHR Surgical MedTech Co-operative, Royal College of Surgeons of England, Royal College of Surgeons of Edinburgh, Sustainable Healthcare Coalition, Association for Perioperative Practice and Brighton and Sussex Medical School.

Background:

After electricity and anaesthesia use, equipment consumption is the largest contributor to the carbon footprint of surgery[1-2]. Laparoscopic surgery is a particularly resource-intensive procedure. Most equipment is single use[1, 5-7], whilst non-specific instrument trays are often opened as standard but unused [8-10].

Acute appendicitis has an incidence of 7-12% in the UK and appendicectomy remains the most performed acute general surgical operation.[11], with 42,000 performed each year. A holistic review of the laparoscopic appendicectomy process reveals many opportunities for improved efficiency which could have a massive cumulative effect and significantly advance the NHS towards its net zero commitments[12-13]. Indeed, by making a range of simple changes to existing processes, protocols and sets, established cultural practices embedded within the system can be challenged and improved to deliver real time sustainable change.

Considerations for sustainable surgery extend beyond the NHS. 17.7 million cases of appendicitis occur globally per year[14] but access to modern best practice surgical techniques in low and middle income countries is limited[15-19]. Gas Insufflation-less Laparoscopic Surgery (GILLS) has been specifically designed to facilitate surgery in these environments with minimal equipment use[20-24]. GILLS doesn't require energy-intensive insufflators, their supporting equipment or disposable specialist instruments, thus reducing consumption substantially.

The Leeds Global Health Research Group have developed Retractor for Abdominal Insufflation-less Surgery (RAIS), a new device aiming to accelerate provision of GILLS. Successful use of the RAIS device would expand global surgical access and contribute significantly towards the UN Sustainable Development Goals[25]. With the impetus of carbon reduction, reverse innovations from these frugal techniques have the potential to transfer these resource-efficient processes into our UK practice[18, 26].

Specific Aims:

To reduce the carbon footprint of the laparoscopic appendicectomy procedure through a holistic approach

1. streamlining the surgical process and reducing equipment consumption
2. exploring the carbon savings available through use of the RAIS surgical device.

Methods:

A multidisciplinary (MDT) approach

An MDT investigative team spanning surgical and medical engineering specialties provided the holistic expertise necessary for this project. The project was coordinated through the Leeds Institute of Emergency General Surgery (LIEGS), with support from the Leeds Teaching Hospitals NHS Trust (LTHT) Sustainability Team and the NIHR MedTech Cooperative in Surgical Technologies, ensuring appropriate representation to relevant stakeholders. Senior team members represent both the NIHR Global Health Research Group in Surgical Technologies (NIHR-GHRG-ST), bringing expertise in Global Surgery needs and innovations like the RAIS device for gasless laparoscopic surgery, and general surgeons specialising in emergency surgical techniques.

Process mapping

Each step of the laparoscopic appendicectomy procedure was mapped out through observation and consultation with the surgical and theatre team. Pre-operative procedures (e.g., catheterisation) and post-operative cleaning were included. Anaesthetic components were excluded as these were beyond the remit of this project. Similarly, post-operative management was not considered, but previous studies of gasless devices have demonstrated no additional analgesic requirements or inpatient stay when compared with traditional laparoscopic methods[23, 27].

Key opportunities were identified and changes implemented, including:

- A pre-operative bladder emptying checklist to eliminate unnecessary patient catheterisation (in favour of able patients emptying their bladder pre-operatively).
- A single 'Green Tray' reduced use of 119 surgical instruments and multiple trays to 49 items per case (excluding camera and light cable). This Green Tray was included in team brief checklist and available to surgeon preference. General instrument trays or additional instruments continued to be readily available but remained unopened until required.
- Opportunities for further change were identified including a switch to reusable equipment trays[4, 9-10, 28], gallipots, kidney dishes, surgical drapes and gowns[28-30], and correct packaging and waste triage[31-32]. Reusable ports had been embedded within the trust for a number of years already.

RAIS Cadaveric Demonstration:

A cadaveric demonstration of the RAIS device compared a control procedure using standard techniques and a full equipment roster, with an intervention procedure using our streamlined procedure and green equipment roster. The aim was to verify the accuracy of the process maps and quantify the resources used during the two variants of the procedure. To accurately simulate both processes; both procedures were carried out in real time with a full operating team assembled. Access to cadaveric samples was approved by Leeds Institute of Medical Education, who ensured procedures were compliant with regulations[33]. The surgeon doing the simulated procedure had used the device before and as such was familiar with it. Engineering team support was available on the day. A video demonstration from the surgeon's perspective is available via this link: https://youtu.be/bD6fwG89IGY.

Equipment changes relevant to the use of the RAIS device included: the potential use of reusable trocars and ports[22, 34-36]. Without pneumoperitoneum, trocar seals are not required[22] and issues regarding leaky reusable trocars are made redundant[37]. RAIS entry to the abdomen (via a supraumbilical incision) permits the easy insertion of equipment, including the use of Roeder knots compared to expensive Endoloop applicators. In certain cases, use of the endoscopic retrieval bag (BERT) and suction equipment can be eliminated too. The elimination of insufflator use also removes the need for disposable insufflation tubing and insufflator CO_2 gas use.

Process maps for both our standard and green procedures are summarised in Appendix 1.

Measurements:

Environmental:

A carbon footprint for all interventions including equipment use and waste generation was calculated using the relevant conversion factors from the UK Government GHG Conversion Factors for Company Reporting 2020, Sustainability Reporting Template 2018/19[54] and Rizan et al 2121[4]. Owing to the discrepancies between human and cadaveric samples, a mean-average insufflator gas consumption of 120L (30 mins) was used for our calculations.

- Production emissions were estimated from procurement costs or material composition. Where multiple unit-costs existed, the modal or lowest was selected. Emissions from transportation of products were also considered.
- Disposal emissions were estimated by product weight and method of disposal. Where applicable, packaging was calculated separately. For reusable equipment, packaging was not measured as all equipment returns in reusable trays.
- Sterilisation of reusable instruments was also considered and included in calculations.
- Scope 2 emissions[2], primarily water and electricity consumption, were not measured and would be identical except for the insufflator (for which an electricity-use was estimated).
- A key aspect of the RAIS device is the elimination of insufflator gas use. A report by Praxair calculated an emissions factor of 2.677kgCO_2e per gaseous litre of carbon dioxide manufactured[38]. This stands in contrast with previous findings that only measured Scope 1 emissions, ignoring manufacturing emissions[39]. No other literature could be found to support or refute these findings[40], and the results were confirmed by the Centre for Sustainable Healthcare (CSH).

Financial:

- Equipment costs were obtained from Trust procurement. BERT Bag and insufflator gas equipment were excluded form calculations as procurement costs were not available. Instrument sterilization cost was estimated from subcontractor figures.

Clinical and social:

- Qualitative data was collected and summarised in the results below.

Results:

Clinical outcomes:

The simulated surgical procedures for both standard and green operations were conducted with no implications for clinical outcomes noted (surgeon view and ability to perform operation). Surgeons commented that intra-abdominal space, camera and instrument access were excellent with the RAIS device, and noted no difficulties using the device or the revised equipment roster and re-usable set up.

There was no increase in procedure time, but it was recognised that there is likely a user learning curve associated with the RAIS device which may prolong initial set-up. There is mixed evidence in previous studies of alternate gasless devices regarding increased operating time[22, 23, 41].

Social sustainability:

Social benefits of increased access to laparoscopic surgery from RAIS in low-resource settings; potential reduction in supply chain labour abuses with move away from single-use surgical equipment, which relies on mass production with minimum labour costs.

Surgical colleagues and Trust representatives expressed motivation to implement green equipment rosters in their specialties.

Environmental sustainability: how much carbon or other environmental resources have been potentially saved?

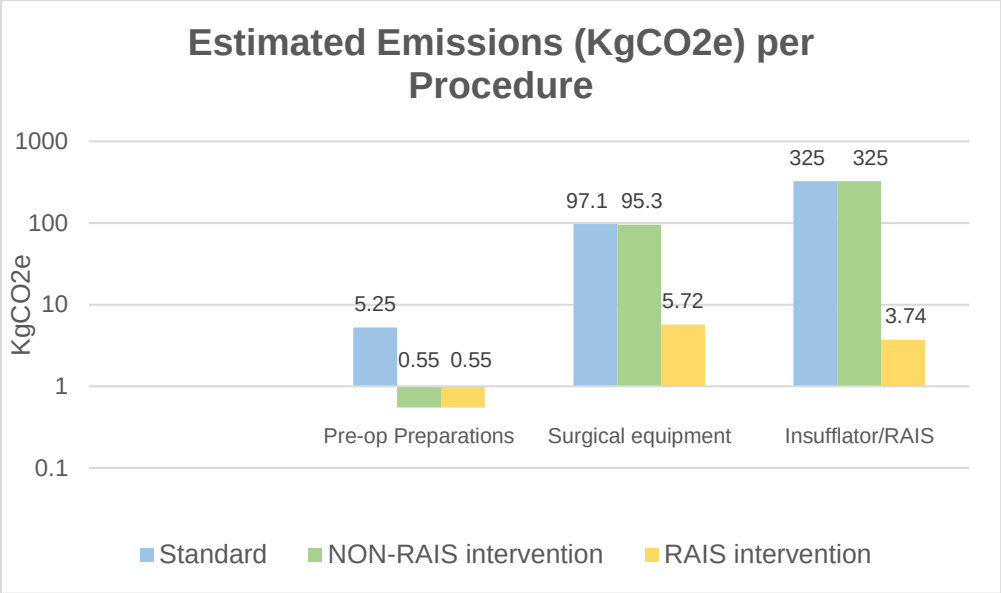


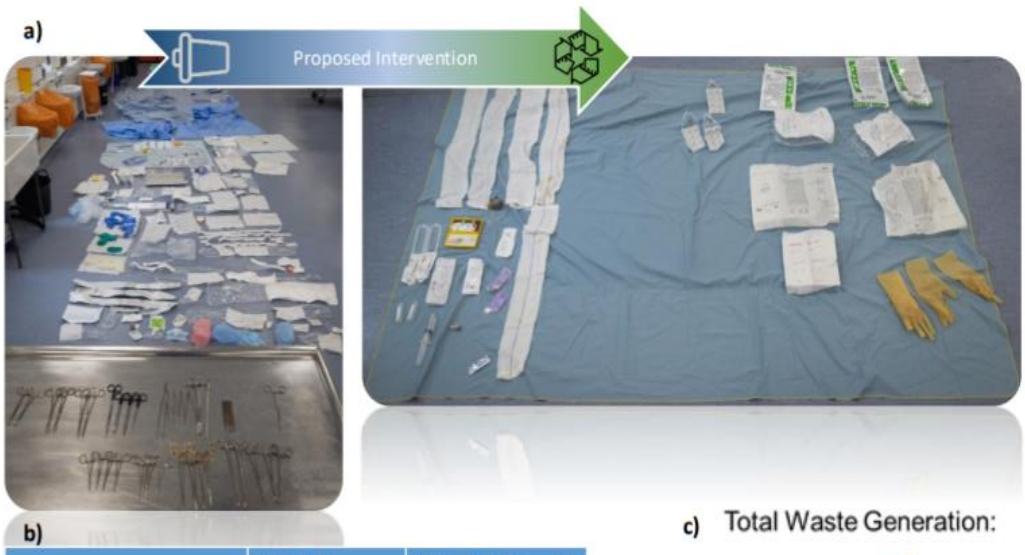
Figure 1. Comparison of emissions produced from standard and proposed surgical procedures (N.B. Log scale)

Non-RAIS Intervention:

Non-RAIS changes can be implemented immediately saving 7.5kgCO2e per procedure, or 3,915kg CO2e per year. Equipment procurement changes accounted for 6.47kgCO2e per procedure and reduced catherization, with 80% applicability, accounted for 863g CO2e per procedure (360kg CO2e per year). These changes could be readily expanded to other operations with minimal effort.

The CO2e saving from waste has been included in the overall CO2e calculations. The amount of waste generated by the standard procedure was 2,291g. 61.7% (1,415g) of this was disposed of as clinical waste. The largest contributors were surgical gowns, drapes, catheterisation, and insufflator tubing which collectively weighed 1,221g. In line with other studies[4, 32, 45], 38.3% of collected waste from the standard operation was packaging related. This should be non-infectious, and much is potentially recyclable[32, 45] but correct waste triage is not always achieved. Stakeholders expressed their shock at the quantity of packaging waste; this could be reduced by supplier and NHS interventions. In addition to the NHS' Net Zero commitment[13], it has made a pledge to reduce plastic consumption[46, 47]. Our intervention reduced waste to 510g, a reduction of 77.74%.

a)



b)

	Standard Procedure	RAIS Device and Green Tray
Procedure success	Yes	Yes
Time	26 mins	18 mins
Instruments used (exc. Camera tray)	119 on two DIN Trays[b]	49 on one DIN tray[b]
Insufflator gas used	120L [c]	*0L
Clinical	1415g	195g
Packaging	876g	315g
All Waste Generation:	2291g	510g

c) Total Waste Generation:

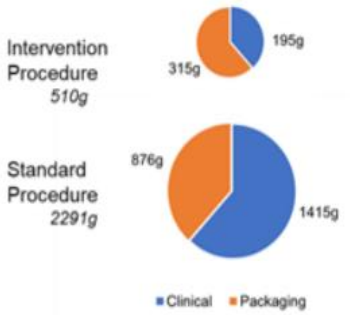


Figure 2. Comparison of outcomes from the proposed interventions showing a) reduction in waste (above), summary of the standard and proposed procedures (b) and total waste generation (c).

RAIS Intervention:

RAIS interventions save an estimated 417.4kgCO2e per surgery; 321kgCO2e of which was due to impact of insufflator gas which dwarfs all other environmental considerations within the scope of this investigation. Longer laparoscopic procedures, such as hysterectomies and cholecystectomies consume even greater quantities of insufflator gas, thus the environmental savings that gasless laparoscopy offers are significant. There is a paucity of accessible statistics regarding medical gas manufacture[38, 40], but the implication for all laparoscopic surgeries is enormous.

Of the remaining 96.2kgCO_2e of saving per RAIS procedure;

- 91.35kgCO2e is due to reduced surgical instrument use and sterilisation.
- 1.78kgCO2e is saved per green tray in sterilisation. With 80% applicability 742kg could be saved annually from this change in Leeds alone.

With 522 appendicectomies taking place in LTHT annually (Jan-Dec 2019) potential savings of up to 217.9 tonnes CO2e can be achieved. Clinicians conservatively estimate a 50% applicability of the RAIS, yielding a modest figure of 108.9 tonnes CO2e. We predict applicability is at 80%, depending on clinician preference and patient-suitability and as such the impact will vary. However, when considering 42,000 annual appendicectomy procedures nationwide[11], savings of up to 82-271.7 tonnes CO2e are achievable.

Economic sustainability – will there be any investment costs? Have any potential financial savings been identified?

Equipment Procurement: Reduced procurement permits savings of up to £299 per procedure. With 80% applicability, £124,862.4 could be saved per year in Leeds alone.

Sterilization: The Green Instrument tray avoids £22.91 per operation in sterilisation. With 80% applicability, £9,567 could be saved annually in Leeds alone.

RAIS device: Investment costs for the RAIS of US $980 (approx. £784) are recuperated within the first year of use, with a projected lifespan of 10 years. Spare parts and refurbishment requirements were not considered in our study but, with annual savings of £78,000 in procurement costs alone from reduced equipment required (50% applicability), RAIS use is a financially advantageous investment.

Barriers encountered:

Surgeon concerns regarding the safety of reusable drapes and gowns pose a potential barrier and should be the subject of increased clarification as there is currently no literature available. We have recently submitted a NIHR trial bid to conduct a non-inferiority trial of reusable drapes and gowns vs disposables and await the outcome of this application.

As highlighted by the GIRFT General Surgery report[51], procurement costs and contracts vary dramatically between different healthcare providers, who do not consolidate their collective purchasing power[53]. Access to procurement figures is difficult; the lack of financial and environmental awareness greatly inhibits decision-making. Close co-operation with the Trust Clinical Procurement team and CSH was essential to ascertain the scope of our interventions. Key financial and environmental statistics, including department and subcontractor energy use, must be readily accessible to empower key stakeholders to take action.

Further exploring and identifying the potential barriers to implementation of these interventions both locally and nationally will help drive potential changes into the future.

Conclusions:

With a holistic approach, we have identified and demonstrated interventions that can be applied immediately in the NHS to reduce equipment consumption. The application of the 'Green Tray' and pre-operative bladder emptying checklist has already been started routinely and the team are focused on the delivering re-usable drapes and packaging moving forward.

These interventions are not specific to laparoscopic appendicectomy, and their dissemination should be greatly encouraged. Colleagues in allied fields have expressed their desire to implement focused instrumentation use, the uptake of which will benefit greatly from our findings. The impact of the pre-operative checklist and focused instrument trays have been implemented already within the Institute of Emergency General Surgery because of this project. Dissemination of our findings to other healthcare providers would permit a wider application of and cumulative effect of these measures. End-user recognition of their impact is vital to sustaining the momentum of interventions, thus regular feedback on local targets is vital. We are currently conducting a survey of operating theatre staff to evaluate the capacity, enthusiasm and barriers for these interventions within each specialty.

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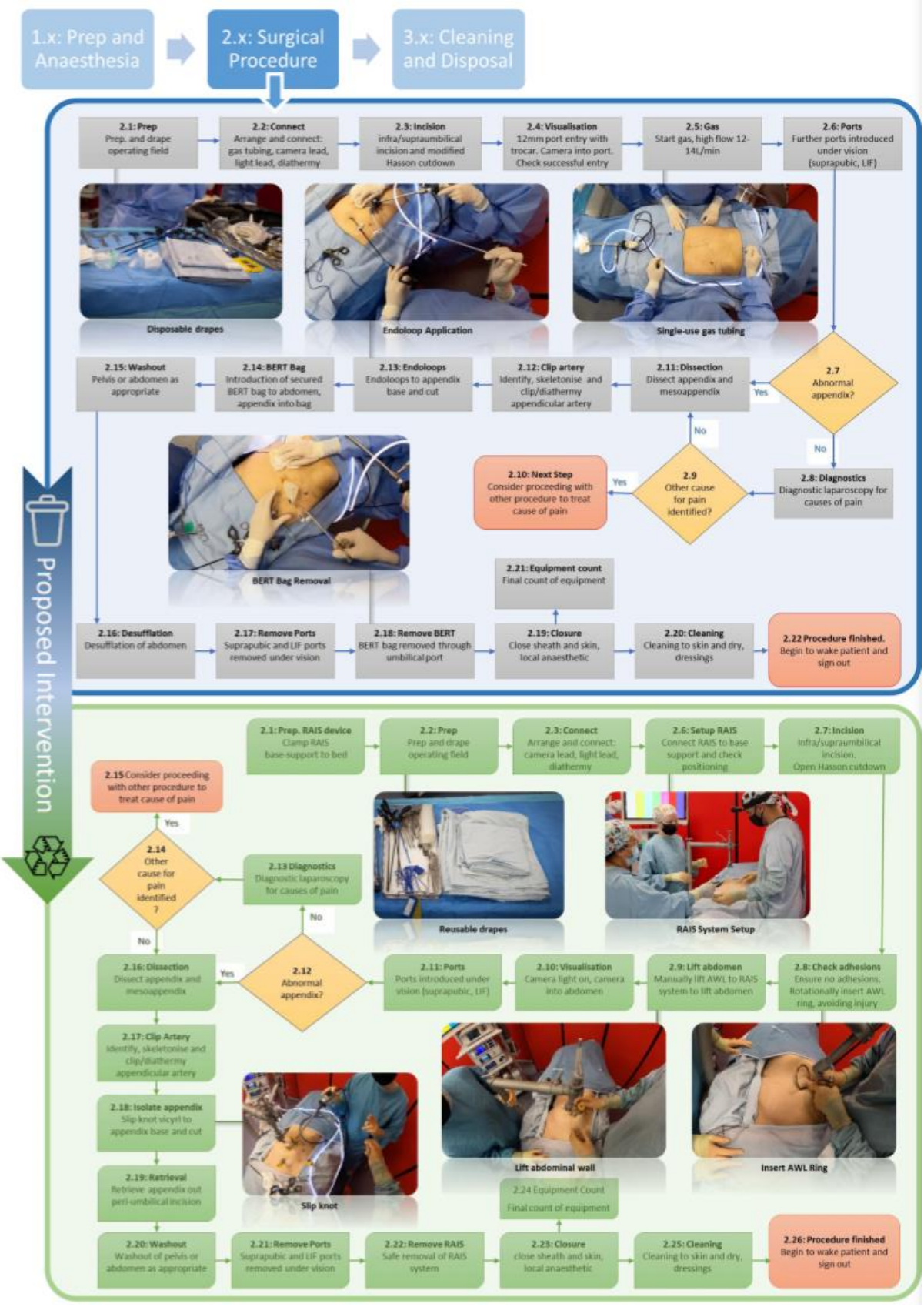
Natural expansions of the RAIS include laparoscopic cholecystectomies and hysterectomies for which precedents of gasless surgery exist[34, 35, 41, 49, 50]. Together, with innovative new surgical approaches like GILLS (using the RAIS device) sustainable approaches can be further enhanced, benefiting the UK and global surgery communities (including those in low resource settings).

Close co-operation with Trust administration, Estates services and industry stakeholders were crucial to evaluate our interventions. Perhaps most crucially, access to the expert opinions of specialists in sustainable healthcare proved invaluable in guiding investigations. As the NHS prioritises sustainability in healthcare, co-operation between sustainability and healthcare experts must be fostered and adequately resourced to realise their ambitions. The maintenance of relationships with industry stakeholders not only provides manufacturing and logistical support but sustains and promotes further innovations. Rutherford Solutions® were involved to ascertain the potential for their reusable surgical drapes and gowns.

Overall, our work highlights the potential to transfer resource-efficient processes into major financial and environmental savings.

Appendix 1: Process maps of the standard (upper) and 'green' (lower) laparoscopic appendicectomy procedure



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