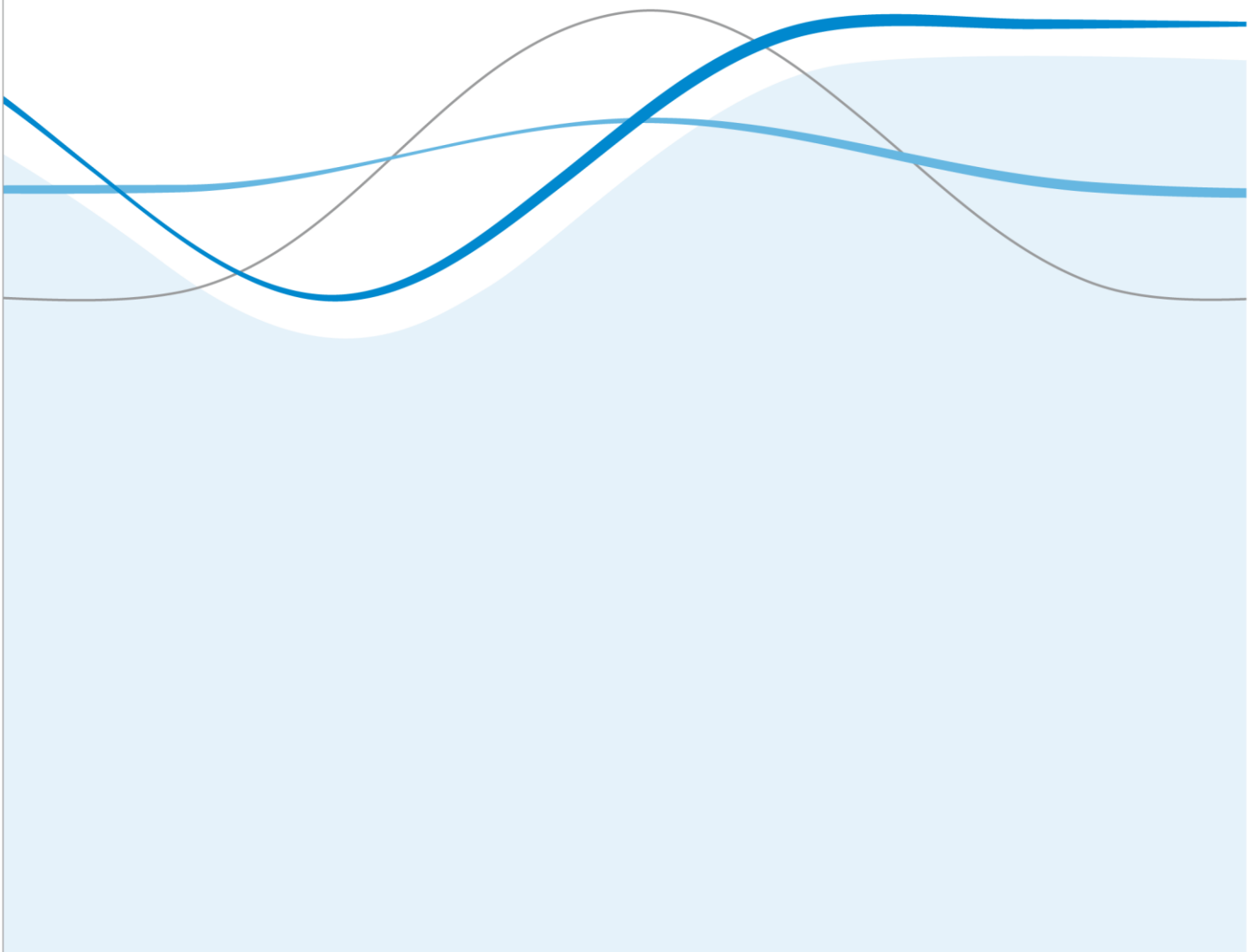


Barriers to Uptake of Minimal Access Surgery in the United Kingdom

March 2018

Amanda Cole, Phill O'Neill, Chris Sampson, Paula Lorgelly



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Office of Health Economics

March 2018

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Funding and Acknowledgements

This study was commissioned and funded by CMR Surgical. The research team would like to thank the consultant surgeons, clinicians and finance and strategic directors who participated in the qualitative interviews.

Please cite this report as:

Cole, A., O'Neill, P., Sampson, C. and Lorgelly, P. (2018). Barriers to Uptake of Minimal Access Surgery in the United Kingdom. OHE Consulting Report, London: Office of Health Economics. Available at: <https://www.ohe.org/publications/barriers-uptake-minimal-access-surgery-united-kingdom>

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EXECUTIVE SUMMARY

The utilisation of minimal access techniques is highly variable across the United Kingdom (UK), and low for many procedures (for example in England less than a quarter of hysterectomies are performed using MAS). This is despite there being a growing evidence base establishing the clinical benefits of minimal access surgery (MAS) over open access surgery. The literature assessed in this report provides an understanding of some of the advantages of MAS for both patients and the health system, including improved and quicker recovery for patients, reduced length of stay in hospital and therefore cost savings to the NHS. Given the benefits, this report asks: what are the opportunities and barriers to realising the benefits of MAS? The evolution of surgical techniques presents an opportunity, including the forthcoming robotic era, so it is important to understand how surgical technologies are adopted in the health care system in the UK and **what challenges are faced when making implementation decisions.**

Why is MAS not utilised more widely? Whilst the literature provides some assessment of the barriers, there was **little evidence in the context of the UK.** We undertook interviews with key stakeholders (surgeons from both NHS and the private sector, clinical directors and finance directors) in England to **identify the barriers to wider MAS uptake.** The mixed methods approach explores the benefits and the barriers, and allows for a commentary on how these barriers could be overcome in order to increase the uptake of MAS and improve patient outcomes.

Thematic analysis of the interviews identified five key (and sometimes overlapping) themes as potentially affecting the uptake of MAS: (1) **the evidence base** and the clinical and cost-effectiveness of MAS, (2) the role of **stakeholders** (hospitals, commissioners, surgeons and patients), (3) **training** requirements, (4) the context of the **service delivery model** (in particular the financial constraints of the NHS), and (5) the forthcoming **robotic era.** These issues are consistent with those identified in a study commissioned by the Royal College of Surgeons on the barriers to innovation in surgery and particularly translational surgical research.

Interviewees generally concurred that there was a robust evidence base for MAS, acknowledging however that considerations need be procedure-specific. This is supported by guidance from the National Institute for Health and Care Excellence (NICE) which supports MAS, yet uptake remains limited and unequal between settings. Beyond patient benefits alone, **business cases** are required to initiate technology adoption decisions, and the increasingly financially constrained NHS means that there is a growing **focus on costs rather than value.**

Commissioners are key decision makers, but often new technology adoption is **championed by individual clinicians.** Such champions will be trained in MAS, which has technically challenging aspects to gain the advanced skills required, but not all surgeons want to be trained (many preferring the open techniques), while others are **not able to receive training.** This was not for lack of training *opportunities*, but often lack of funding and/or time to take advantage of these opportunities.

All of this is in the context of the service delivery model, and a financially constrained NHS. The **barrier posed by the constrained capacity** of (suitably trained) clinical staff **must be overcome if MAS uptake is to be improved;** advancements in MAS are currently outpacing the capacity and training of staff to deliver them. However, a constrained estate (the NHS "bed crisis") should be considered a motivator for MAS,

which is associated with a shorter length of hospital stay and can therefore free-up much needed bed space, also enabling cost savings for the NHS. Ultimately uptake may increasingly be driven by **patient choice**; increasing patient-centricity may mean supply has to meet demand. The introduction of **robotics could be the catalyst to achieving improvements in uptake of MAS**, allowing wider utilisation of MAS by more surgeons and for more procedures. However, the cost is such that its adoption has thus far been relatively limited.

A number of **solutions to overcome these barriers** are recommended, including the break-down of budget silos, the increased utilisation of financial incentives, improved referral practice and collaboration between clinicians, better investment in and encouragement of training in MAS, and better health service planning.

Particularly in the context of a constrained NHS, there is a growing awareness of the need to promote innovation which can realise improvements in patient care and outcomes, and help to build a sustainable health system for the future. This will create an ideal environment to **address these barriers and harness the benefits of MAS**.

1. INTRODUCTION

The introduction of new clinical interventions, be they pharmaceuticals, devices, diagnostics or practices, presents specific challenges for healthcare providers in the public and private sectors, especially when associated with upfront investment costs in capital, training or other commitments. Whether and how these challenges (or barriers) are addressed will determine the extent of the diffusion and uptake of a technology.

The theory of technology diffusion is extensive. The seminal work of Everett Rogers on the *Diffusion of Innovations* defines categories of 'adopters', separating them into innovators, early adopters, early majority, late majority and laggards (Rogers, 1962). This corresponds with an s-shaped 'diffusion curve' marked by three phases: 'incubation' in the early phases where technology adoption rises slowly but at an increasing rate, 'exponential growth' where adoption increases rapidly and then slows as it approaches 'saturation' where laggards adopt the technology but at a diminishing rate. Greenhalgh et al. (2004) outline nine main considerations in the diffusion of innovations: the innovation itself, the potential adopter, communication and influence, system antecedents, system readiness, the 'outer context', the process of assimilation, the implementation process, and the linkage between the components (Merkel et al., 2015; Greenhalgh et al., 2004).

Given the complex considerations involved in the selection of surgical route, which will differ according to the procedure as well as on a patient-by-patient basis, it is difficult to quantify the level of 'under-utilisation' of MAS. However, it is evident that uptake differs substantially by procedure, as well as by individual hospital. There is therefore a need to understand the nature of this variation and, where relevant, how barriers can be overcome which are inhibiting the uptake of MAS and the positive impact it can have on patient outcomes and the efficient use of resources.

The development and use of minimal access techniques has been a feature of surgery for the last thirty to forty years. From early use of laparoscopic equipment, to increasing robotic assistance in surgery, these techniques have been at the forefront of surgical innovation. They are enabling more complex procedures to be attempted and resulting in improved clinical outcomes for patients. They have also changed the dynamics of the costs and benefits in terms of theatre costs and inpatient stays.

To understand the mechanisms of technology adoption in surgical practice this report will assess:

- the relative merits of minimal access surgery (MAS) in the UK,
- the barriers to the uptake of MAS, and
- the benefits of addressing the barriers to the uptake of MAS.

1.1. Evolution of surgical techniques, their benefits and utilisation

The growth in the use of laparoscopic surgery (or MAS as it will be referred to herein, noting that it is also known as keyhole surgery or minimally invasive surgery) can be traced back to the mid- to late- 90s. The pioneering work of Kurt Semm on laparoscopic appendectomies (once accepted by the surgical community (Bhattacharya, 2007)) and of Erich Mühe on laparoscopic cholecystectomy (Litynski, 1998), resulted in the first revolution in surgical education and training courses. Himal (2002) notes "(f)or the general surgeon, the unparalleled success of laparoscopic cholecystectomy became the stimulus for expanding the role of minimally invasive surgery". Writing at the start of

this century he concludes “minimal invasive surgery has become the most important part of general surgery”.

There is a growing evidence base, discussed further in this report, establishing the clinical benefits of the use of MAS over open surgery in many procedures, including reduced risk of post-operative complications such as wound infections and venous thrombosis, decreased pain and use of narcotics, and reduced length of hospital stay and shorter time to return to normal activity. Although the economic benefits are more equivocal, as they depend in some cases on the technology adopted to facilitate MAS, it would be reasonable to expect that the use of MAS would increase for those procedures where clinical benefits have been demonstrated, and where there is evidence to support the cost-effective delivery of MAS.

In a recent analysis of hospital episode statistics in England, Marcus et al. (2017) examine prostatectomies, partial nephrectomies and total abdominal hysterectomies, and compare over time (2006/07 to 2014/15) whether the procedures were undertaken using open, laparoscopic or robotic surgery. Each procedure showed variation in uptake by surgery type but with the common theme that rates of open surgery are declining over time. Laparoscopic total abdominal hysterectomies have increased since 2010, although remain low at approximately 23.6% of the total number performed in 2015/16; moreover, robotic assisted hysterectomies are only a small share of the NHS market (1.4%). Conversely, for prostatectomy, the analysis showed that since 2011 laparoscopic procedures have started to decline, while robotic surgery has diffused rapidly (in 2014 the majority of prostatectomies (62.7%) were performed robotically in the NHS in England).

While there appears to have been an overall increase in the use of laparoscopic or robot assisted MAS in the NHS, this may mask variation in rates of uptake between NHS Trusts. Overall, uptake in England may be driven by a small number of Trusts and in the absence of a benchmark it is difficult to establish whether the rate of MAS uptake is ‘good’.

1.2. Objective of the report

Given the evolution of surgical techniques including the use of robot-assisted surgery, it is important to identify the barriers to the uptake of MAS in clinical practice, and the value of overcoming those barriers before wider adoption and implementation can be considered.

An initial review of the literature establishes the relative merits of MAS versus open access surgery, and offers a summary of the evidence for MAS in the context of three specific procedures. This is followed by a summary of the literature examining the barriers to the adoption of MAS. There is no comprehensive inquiry and analysis of the barriers, particularly in the context of the United Kingdom (UK). Therefore, interviews with key stakeholders in England were undertaken *to identify the barriers to MAS*, both financial and clinical. A mixed methods approach allows an exploration of the benefits and the barriers of increasing the uptake of MAS in the UK.

We focus on three specific areas of surgery:

- gynaecology (specifically hysterectomy),
- lower abdominal (specifically ventral / incisional hernia repair), and
- colorectal (specifically lower anterior resection).

There is likely to be an under-utilisation of MAS in these areas: recommendations to support MAS in these procedures have been made, but uptake remains relatively low. This allows us to explore the issues in the literature and also qualitatively with stakeholders.

2. LITERATURE REVIEW

2.1. Method

Focusing on the three procedures highlighted above (hysterectomy, ventral/incisional hernia repair and lower anterior resection), a systematic approach was taken to identify the literature pertaining to the clinical and economic impact of MAS relative to open-access surgery. The clinical literature was identified through a search of scholarly articles of the MEDLINE database (through PubMed). Given the very high volume of publications in the clinical literature for this topic, we applied various filters to narrow our search results. We filtered results to those published in the English language and published in the last five years. We also applied a study design filter to capture systematic reviews only. Systematic reviews represent the highest level of evidence, as they are designed to provide a complete and exhaustive summary of the relevant literature. Meta-analyses, which are often conducted as part of a systematic review, produce effect size estimates which are based on the results of the multiple studies included. This aims to reduce any biases that might be present in any individual study, and can quantitatively analyse the uncertainty around the parameters reported, and also take into account any potential reporting bias. In recognition of the time delay in the conduct and publishing of systematic reviews, we supplemented the results with a search utilizing the same terms, without the systematic review study design filter, applying a restriction of the past two years. This was to ensure that we captured the results of the most up-to-date clinical trials. The procedure-specific search terms and search strategy that were used are specified in Appendix 1.

In addition to reviewing the literature relating to the clinical and economic impact of MAS, we also identified research articles that discussed the barriers to access of MAS. These papers helped inform the subsequent interview schedule.

Finally, given the technological developments with robotics, we also thought it pertinent to provide a brief overview of some of the recent literature on the implementation, uptake and barriers with regards to robotic MAS specifically.

2.2. Summary of the literature

2.2.1. Hysterectomy

Our search on the clinical impact of MAS identified two relevant systematic reviews of the literature with respect to hysterectomy. As per our search criteria these papers reviewed the trials comparing open surgery to laparoscopic surgery; He et al. (2013) reviewed 9 randomised controlled trials (RCTs) comparing laparoscopic surgery with laparotomy for the treatment of endometrial cancer, while Wang et al. (2015) reviewed 12 observational studies that compared laparoscopic radical hysterectomy with open radical hysterectomy for early stage cervical cancer.

Both reviews found that MAS had benefits over open surgery, including a significantly shorter length of hospital stay (3.22 days, 95% CI -4.21,-2.23 (Wang et al., 2015); 3.42 days, 95% CI -3.81,-3.03 (He et al., 2013)) and significantly lower rates of post-operative complications (10.1% vs 20.1%, OR=0.46 (Wang et al., 2015); 15.8% vs

23.4%, OR=0.62 (He et al., 2013)). Wang et al. (2015) also report significantly lower intraoperative blood loss (weighted mean difference = -268.4 mL, 95% CI -361.6,-175.1). These benefits however come at the expense of a longer operative time: Wang et al found that on average a laparoscopic radical hysterectomy took 26.9 minutes longer (95% CI 8.08,45.82); He et al. (2013) found that laparoscopic surgery for endometrial cancer took on average 32.7 minutes longer (95% CI 16.34,49.13). In terms of primary endpoints both systematic reviews reached the same conclusion that there was no significant difference in survival (3 year overall survival (OS) endometrial OR=0.91, 95% CI 0.49,1.71; 3 year disease free survival (DFS) endometrial OR=0.95, 95% CI 0.29,1.80 (He et al., 2013); 5 year OS cervical HR=0.91, 95% CI 0.48,1.71; 5 year DFS HR=0.97, 95% CI 0.56,1.68 (Wang et al., 2015)), recurrence (endometrial at 3 years OR=1.11, 95% CI 0.08,14.52 (He et al., 2013)) or lymph node (mean difference -1.06, 95% CI -4.03,1.91 (Wang et al., 2015)) or pelvic node yield (mean difference 0.45, 95% CI -0.41,1.32 (He et al., 2013)).

The literature review with respect to economic evidence was generally supportive of the use of MAS in hysterectomies. A variety of studies have identified that MAS is associated with lower total costs compared with open surgery hysterectomy (Rhou et al., 2015; Fitch, Engel and Bochner, 2015; Shepherd et al., 2014; Coronado et al., 2012). Specifically Rhou et al. (2015) found that laparoscopic hysterectomy was associated with significantly higher interoperative costs (AUD\$3877 vs AUD\$2776, $p < 0.001$, 2012 prices) but significantly lower postoperative costs (AUD\$3965 vs AUD\$6233, $p < 0.001$). Ultimately the total costs of each procedure were not significantly different (AUD\$7842 vs AUD\$9009, $p = 0.068$), and notably the cost of laparoscopic hysterectomy significantly declined after a period of learning (so called learning-curve effect) (AUD\$6797 vs AUD\$8647, $p < 0.001$). The post-operative savings are a result of MAS reducing the length of stay compared with open surgery in hysterectomy (Baffert et al., 2016; He et al., 2013; Yu et al., 2013; Zanagnolo et al., 2016; Wang et al., 2015). For example, Baffert et al. (2016) reports a difference of 1.6 days (7.3 vs 5.7 days, $p < 0.001$) between laparotomy and laparoscopic hysterectomies. Baffert et al. (2016) also found evidence that MAS for patients with cervical cancer was associated with fewer patients using convalescence homes (4 vs 0, $p = 0.01$) and thus more patients recovered at home resulting in further savings for the health care system.

Specifically with respect to robotic assisted MAS, a recent retrospective observational study reported clinical benefits and resource use savings with robotic radical hysterectomy when compared to laparotomy. Zanagnolo et al. (2016) reported shorter surgical times, significantly less blood loss, significantly higher number of lymph nodes removed, and a significantly shorter hospital stay. Coronado et al. (2012) in a retrospective review of patients treated for primary endometrial adenocarcinomas via either robotic assisted laparoscopy, laparoscopy or laparotomy also reported similar significant benefits: lower blood loss (99.4 ml in robotic vs 190.0 ml in laparoscopy vs 231.5 ml in laparotomy, $p = 0.000$); smaller differences in hemoglobin levels (-1.3g/dl, -2.3g/dl and -2.5 g/dl respectively, $p = 0.000$); lower transfusion rate (4.2%, 7.1% and 14.1% respectively, $p = 0.036$); and shorter length of stay (3.5, 4.6 and 8.1 days respectively; $p = 0.000$). The conversion rate to laparotomy was lower for robotics (2.4% for robotics and 8.1% for laparoscopy, $p = 0.181$). In their cost analysis they found that while robotic laparoscopy was more expensive (€5048, €4594 and €4680 respectively) the difference was not significant ($p = 0.394$).

2.2.2. Hernia

Our search on the clinical impact of MAS for hernia repair identified four relevant systematic reviews. Zhang et al. (2014) undertook a systematic review and meta-analysis of eleven RCTs comparing laparoscopic incisional and ventral hernia repair (LIVHR) to conventional open surgery (OIVHR). Awaiz et al. (2015) conducted a meta-analysis of six studies which compared only elective incision hernia by open and laparoscopic surgery. Al Chalabi et al. (2015) identified five RCTs comparing laparoscopic and open abdominal incisional hernia repair. Arita et al. (2015) reviewed five and fifteen studies comparing laparoscopic and open repair for ventral hernias for primary (PVH) and incisional (IVH) cohorts, respectively. In general the reviews found that laparoscopic and open repair of hernias are comparable, although there are benefits to MAS with respect to wound/surgical site infection rates.

Three systematic reviews found that wound infection rates were significantly lower in laparoscopic surgery compared with open surgery (2.8% vs 16.2%, RR=0.19, $p < 0.001$ (Zhang et al., 2014); RR=0.22, 95% CI 0.11,0.44, $p < 0.001$ (Al Chalabi et al., 2015); 2.3% vs 9.2% for PVH, OR=4.17, 95% CI 2.03-8.55 and 1.6% vs 10.1% for IVH, OR=5.16, 95% CI 2.79,9.57 (Arita et al., 2015)). The other review found that wound infection rates were similar with respect to studies of elective incision hernia repair (OR=0.49, 95% CI 0.09,2.67, $p = 0.41$ (Awaiz et al., 2015)). There is also evidence that wound drainage rates are significantly lower in laparoscopic surgery compared with open surgery (2.6% vs 67.0%, RR=0.06, $p < 0.001$ (Zhang et al., 2014)).

All the systematic reviews found that hernia recurrence rates were similar (6.99% laparoscopic vs 4.82% open, RR=1.21, $p = 0.41$ (Zhang et al., 2014); OR 1.41, 95% CI 0.81,2.46, $p = 0.23$ (Awaiz et al., 2015); RR=1.29, 95% CI 0.79,2.11, $p = 0.30$ (Al Chalabi et al., 2015); 3.6% laparoscopic vs 4.3% open primary repair, OR=0.95, 95% CI 0.46,1.98 and 8.5% laparoscopic vs 10.1% open incisional repair, OR=1.14, 95% CI 0.81,1.60 (Arita et al., 2015)). Likewise, rates of reoperation rate were similar (RR=0.42, $p = 0.07$ (Zhang et al., 2014); OR=-0.32, 95% CI 0.07,1.43, $p = 0.14$ (Awaiz et al., 2015)).

There was mixed evidence regarding operation time. Zhang et al. (2014) found considerable heterogeneity in the studies they reviewed and could not undertake a pooled analysis, although reported that six studies (of eleven) found significant differences; two reported that laparoscopic repair was faster, and four found that open surgery was faster. Awaiz et al. (2015) and Al Chalabi et al. (2015) found no significant difference between operation times in their meta analyses (standardised mean difference between laparoscopic and open, SMD=-0.08, 95% CI -4.46,4.30, $p = 0.97$ (Awaiz et al., 2015); weighted mean difference between open and laparoscopic, WMD=15.23, 95% CI -0.12,30.58, $p = 0.05$ (Al Chalabi et al., 2015)).

Zhang et al. (2014) also reported heterogeneity in the studies with respect to length of stay. In descriptive analysis (rather than pooled analysis) they report that six studies found significantly shorter length of hospital stay for those patients receiving laparoscopic hernia repair, while the other five reported no statistically significant difference. No difference in length of stay was also reported by Awaiz et al. (2015) and Al Chalabi et al. (2015) in their systematic reviews (SMD=-0.83, 95% CI -2.22,0.56, $p = 0.24$ (Awaiz et al., 2015); WMD=0.01, 95% CI -0.22,0.24, $p = 0.92$ (Al Chalabi et al., 2015)).

Note that two systematic reviews found evidence that bowel injury/complications were significantly higher in laparoscopic surgery than with open surgery (4.3% vs 0.81%, RR=3.68, p=0.003 (Zhang et al., 2014); OR=2.56, 95% CI 1.15,5.72, p=0.02 (Awaiz et al., 2015)).

Although not considered in the systematic reviews there is evidence to suggest that MAS for hernia repair is associated with significantly reduced blood loss (13.0 mL vs 31.5 mL, p=0.028 (Ahonen-Siirtola et al., 2015)).

We also identified papers that showed that MAS has been found to be beneficial in high risk hernia patients, including those who are obese (Froylich et al., 2016) and those with chronic liver disease (Juo et al., 2017). In a retrospective review of patient case notes from 2004 to 2011, Froylich et al. (2016) found that despite laparoscopic repairs being performed on significantly larger hernias, perioperative complications (17.1% vs 20.5%, p=0.53), wound related complications (5.7% vs 15.8%, p=0.09) and recurrence rates (20.0% v 27.1%, p=0.28) were similar between laparoscopic and open procedures. Length of stay was similar (3.2 vs 3.8 days, p=0.23) although operative time was significantly longer (102 vs 67 minutes, p<0.001). Juo et al. (2017) identified chronic liver disease patients who had undergone elective ventral hernia repair between 2005 and 2013, either laparoscopically or via open surgery. Their analysis found that laparoscopic repair was associated with a lower incidence of wound-related complications (OR=0.23, 95% CI 0.07,0.74, p=0.01), shorter length of stay (3.7 vs 5.0 days, p<0.01) but similar systemic complications (OR=0.92, 95% CI 0.53,1.59, p=0.77), bleeding complications (OR=0.82, 95% CI 0.32,2.14, p=0.69) or unplanned reoperation (OR=0.88, 95% CI 0.43,1.83, p=0.74). Notably when they controlled for ascites they found that laparoscopic ventral hernia repair was associated with higher perioperative mortality (OR=5.36, 95% CI 1.00,28.60, p=0.05).

The literature review with respect to economic evidence found a variety of studies have identified that MAS is associated with lower total costs compared with open surgery for ventral hernia repair (Ecker et al., 2016; Fitch et al., 2015). Ecker et al. (2016) in a longitudinal study of a US healthcare claims database (2007-2011) found that laparoscopic ventral hernia repair cost significantly less than open repair (USD\$1014, 95% CI USD\$309,USD\$11,719, p=0.005). This was due to a shorter median length of stay (2 vs 3 days, p<0.001) and a lower rate of prolonged length of stay (5.0% vs 10.2%, p<0.001). The longitudinal analysis found that this cost difference persisted after a year due to fewer readmissions. Fitch et al. (2015) also undertook an analysis of a claims database. They reviewed claims between 2011 and 2012 for colectomy, ventral hernia repair, thoracic resection and hysterectomy comparing the cost of those procedures undertaken minimally invasive and open. They considered the costs during the inpatient stay and so 30 days after discharge, which included outpatient and prescription costs and any further inpatient stays. They found that for all types of laparoscopic surgery the cost per episode was lower, specifically with respect to ventral hernia repair the (adjusted) cost difference was USD\$5,401 per episode (p<0.001).

2.2.3. Lower anterior resection

The targeted literature search identified a recent article by Krane and Fichera (2012) which reviewed eight prospective RCTs, three meta analyses and two Cochrane systematic reviews in order to provide an overview of the outcomes of laparoscopic rectal cancer resection. Krane and Fichera (2012) report that in four of six RCTs intraoperative blood loss was significantly less for laparoscopic patients compared to

open patients, ranging from 20 to 321.7 mL in laparoscopic surgery compared to 92 to 555.6 mL in open surgery. They also report that this aligns with a Cochrane review Breukink, Pierie and Wiggers (2006) of elective laparoscopic total mesorectal excision (TME) which found that in the majority of studies a laparoscopic approach reduced blood loss, although this did not translate to fewer transfusions. The other intraoperative outcome Krane and Fichera (2012) report is operative time. For open surgery this ranged from 106 to 284 minutes compared to 120 to 245 minutes for laparoscopic resection RCT that they reviewed. A longer operative time was also confirmed in a meta analysis; Aziz et al. (2006) reported a weighted mean difference (WMD) in operating time of 40.18 minutes (95% CI 26.46,56.13) in their review of 22 RCTs. However the other meta analysis they identified (Gao, Cao and Chen, 2006) found no difference in operating time (WMD=1.59, 95% CI 1.2,1.98) when pooling 11 studies.

In an assessment of short term outcomes Krane and Fichera (2012) considered a number of outcomes including the number of lymph nodes retrieved, postoperative pain, bowel function, length of stay, complications and long term outcomes including recurrence and survival. With respect to lymph nodes retrieved, six of eight RCTs reported the laparoscopic group mean ranged from 5.5 to 17 nodes, while the open group mean ranged from 11.6 to 18 nodes. In four of these studies the difference was not significant, one reported that the laparoscopic technique retrieved more (Lujan et al., 2009) while the other reported a significantly lower yield using laparoscopic surgery (Araujo et al., 2003). Three RCT compared postoperative pain medication (as a proxy for pain), two of these reported a significant reduction in analgesic use in the laparoscopic group (8.3 v 4.9 mg (Ng et al., 2009); 11.4 vs 6.0 (Ng et al., 2008)). The majority of studies reported earlier bowel movements and the ability to tolerate solid food in the laparoscopic group (comparable statistics not reported). Improved bowel function and less pain is thought to result in earlier discharge for laparoscopic surgery, although in their review Krane and Fichera (2012) the RCT did not find a significant difference between surgical approaches, but reported a trend towards a decreased length of stay with laparoscopic rectal surgery (three studies reported a significant reduction in length of stay for the laparoscopic group: 10.0 vs 8.4 days (Ng et al., 2009); 13.6 vs 10 days (Braga et al., 2007); 13.3 vs 8.1 days (Zhou et al., 2004)). Breukink et al. (2006), a Cochrane review, also confirmed many of these short term benefits: laparoscopic TME was found to result in earlier return to normal diet, less pain, less pain medication and shorter hospital stay. Krane and Fichera (2012) found that wound infections and urinary tract infections accounted for the majority of perioperative complications. In their review of RCTs they found a higher incidence of infections in the open group, but the difference was not statistically significant; one of the meta analyses (Aziz et al., 2006) and the Cochrane review (Breukink et al., 2006) also found no difference in infection rates, while Gao et al. (2006) found they were significantly lower in the laparoscopic group. Six of eight RCTs considered recurrence, while there was a trend for lower recurrence in the laparoscopic group (4% to 9.7%) compared with the open group (5.2% to 11.1%) the difference was not significant. This was also confirmed in a meta analysis (Anderson, Uman and Pigazzi, 2008). Four RCTs considered survival (overall and disease free), laparoscopic and open surgery were found to have comparable survival rates; also confirmed in a meta analysis (Anderson et al., 2008). Note that the Cochrane review that Krane and Fichera (2012) refer to (Breukink et al., 2006) has been subsequently updated. Vennix et al. (2014) in a review that specifically focused on the technique of TME confirms the earlier findings. Laparoscopic and open TME have similar long-term results (local recurrence: OR=0.89, 95% CI 0.57,1.39; OS rate: OR=1.15, 95% CI

0.87,1.52) but there are short-term benefits of laparoscopic over open TME, including shorter length of hospital stay (-2 days, 95% CI -3.22,-1.10), shorter time to first defecation (-0.86 days, 95% CI -1.17,-0.54), fewer wound infections (OR=0.68, 95% CI 0.50,0.93) and fewer bleeding complications (OR=0.30, 95% CI 0.10,0.93).

We also identified papers that showed that MAS has been found to be beneficial in high risk rectal cancer patients, including those who are obese (Matsuzaki et al., 2017) and those with advanced stage cancer (De'Angelis et al., 2017). In a review of patient case notes from 2008 to 2015, Matsuzaki et al. (2017) compared open and laparoscopic anterior resection for rectal cancer in non-obese and obese (BMI \geq 25) patients. The operative time for laparoscopic surgery in the non-obese group was significantly longer (266 vs 189 minutes, $p<0.001$) but not in the obese group (260 vs 254 minutes, $p=0.965$). The clinical outcomes suggested benefits of laparoscopic over open surgery or comparable findings: median blood loss was significantly lower for laparoscopic surgery in both non-obese (10 vs 275 mL, $p<0.001$) and obese (10 vs 435 mL, $p<0.001$) patients, no difference in surgical site infection rates for non-obese (3.5% vs 2.3%, $p=0.70$) or obese (6.8% vs 0%, $p=0.548$) patients, and no difference in overall complications for non-obese (18.5% vs 11.6%, $p=0.180$) or obese patients (18.2% vs 20.0%, $p=1.000$). De'Angelis et al. (2017) undertook a multi-centre propensity score matching study to compare outcomes of patients with T4 rectal cancer undergoing either laparoscopic anterior resections or open anterior resections between 2005 and 2015. Their matching analysis found no difference in operative time (244.5 vs 250 days, $p=0.737$) or blood loss (120 vs 150 mL, $p=0.178$). Patients receiving laparoscopic resection demonstrated a significantly shorter time to flatus (3.13 vs 4.97 days, $p=0.001$) and time to regular diet (3.59 vs 6.36 days, $p<0.001$), which translated into a significantly shorter inpatient stay (15.49 vs 17.96 days, $p=0.002$). Mesorectal excision was similar in both (82.7% of laparoscopic vs 78.8% of open, $p=0.855$) as was overall survival (3 year survival 66.7% for laparoscopic vs 64.1% for open, $p=0.219$, overall).

A review of the economic literature identified a paper which estimated both the direct and indirect costs of laparoscopic anterior resection compared to open resection (Feng et al., 2010). Feng et al. (2010) undertook an economic analysis alongside a non-RCT assessing direct costs (medications, surgical instruments and device, transfusions, hospitalisations and complication costs) and indirect costs (financial loss due to absence from work). The analysis found that while the total costs of each procedure were similar (RMB27,923 open vs RMB27,054, $p=0.859$), the pharmaceutical spend, the nutritional support, hospitalisation cost and indirect costs were significantly lower in the laparoscopic group. The shorter length of stay of laparoscopic surgery (16 vs 23 days, $p<0.01$) resulted in benefits for both the hospital and the patients who were able to return to work in nearly half the time (26 vs 44 days, $p<0.01$). Notably the recent Cochrane review also set out to analysis the costs of laparoscopic and open TME, but could not undertake a meta-analysis due to the heterogeneity of the estimates. As an example King et al. (2006) reported median direct and indirect costs of laparoscopic TME of £6433 and £6786 for open, while Franks et al. (2006) report costs of laparoscopic TME of £8259 and £7820 for open. Neither result achieved a statistically significant difference.

2.3. Barriers to access of MAS

A review of the literature identified the following four main barriers to the adoption of MAS and its wider uptake.

2.3.1. Training

Fuchs Weizman et al. (2015) and Einarsson et al. (2010) argue that training in MAS techniques are a barrier to greater adoption of MAS. Cooper et al. (2014) considers the issue to be twofold: lack of formal training opportunities and adequate operating time. The technical difficulty of performing MAS is such that advanced training opportunities are required, which may not always be provided by the mainstream training on offer. For example, a survey of trainees undertaking an MAS residency program in Belgium identified that only 29% of gynaecologists, 27% of urologists and 52% of general surgeon respondents felt capable of performing MAS at the end of their training; advanced fellowships were considered by most to be necessary to achieve the required skills (De Win et al., 2015). The complexity of laparoscopic suturing was specifically identified by Lim et al. (2017) as a barrier to laparoscopic surgery, and as a training need.

2.3.2. Health literacy

Janda et al. (2017) found that if patients were better informed about the options for surgery then they were more likely to receive MAS. Based on a study (Whelan et al., 2004) examining patient choices for minimal invasive surgery and breast conserving therapy, Cooper et al. (2014) speculate that better patient education would increase utilisation. Supporting this conjecture, Hawkins et al. (2018) found that areas in the US with low education (high rates of failing to graduate high school) exhibited significantly lower rates of laparoscopic colon resection.

It should be noted that, in the UK, the 'Montgomery ruling' of 2015 states that all patients should be made aware of all treatment risks and alternative treatment options during the consenting process (Godlee, 2015). If applied correctly, this supports shifting the onus onto clinicians to describe the available options, and refer to other practitioners where required.

2.3.3. Size/location of hospital

Cooper et al. (2014) found that larger hospitals in the US had a higher rate of MAS utilisation. They also associated teaching hospitals with a greater rate of utilisation. The authors identified a disparity between private and public funded hospitals with the latter having a higher utilisation rate.

2.3.4. Volume of surgery and the learning curve

Surgical volume was identified as a factor in MAS utilisation by Cooper et al. (2014), Fuchs Weizman et al. (2015), Einarsson et al. (2010) and Hawkins et al. (2018). Surgeons (or centres) undertaking a greater number of procedures were found to have a higher utilisation rate of MAS. For example Hawkins et al. (2018), in an analysis of the factors associated with MAS uptake in colon resection for cancer, found that treatment at low-volume centres was associated with decreased odds of utilising a laparoscopic approach. The issue of surgical volume is related to the concept of the 'learning curve'. The technical difficulty of the procedure means it can require significant time to master, (and indeed may be beyond the ability of some surgeons irrespective of opportunity and training). For example, in considering the learning curve associated with becoming proficient in laparoscopic sacrocolpopexy, Claerhout et al. (2014) demonstrate how quality improves over time, and show that it took a trainee over 30 procedures to achieve an operation time equivalent to that of the teacher.

2.4. Robotic evidence and barriers to uptake

Hughes-Hallett et al. (2015), in their analysis of technological innovation in MAS, speculate that the transition of single incision MAS from specialist to mainstream may be facilitated by improvements in tools to perform the technique, with a likely role for robotic surgery. The rapid development of robotic devices to assist in the delivery of MAS is such that there has been increasing evidence on the clinical and cost-effectiveness of robotic-assisted MAS. We summarise some of the most recent literature below, first in terms of the economic evidence and then in terms of possible barriers.

2.4.1. Economic evidence base

A recent economic evaluation of the implementation of robotics into a NHS endometrial cancer service found that while the median operating time increased by 37 minutes compared to open surgery, the length of stay was 2 days shorter and complications reduced from 49.2% to 28.8%. Costs reduced from £11,476 to £10,274 per case (Ind et al., 2016).

Assessing the four most common laparoscopic techniques in the US in 2008 (radical prostatectomy, nephrectomy, partial nephrectomy and pyeloplasty) Yu et al. (2012) report that, compared with open surgery, robot-assisted laparoscopic and laparoscopic procedures were generally associated with shorter length of stay and fewer complications (including cardiac, wound, respiratory and vascular), although robot-assisted laparoscopic surgery had greater median costs. On average, for all four procedures, robot-assisted laparoscopic surgery was associated with cost of USD\$13,063 compared with USD\$10,482 for laparoscopic and USD\$10,895 for open. Given the advantages of robot assisted surgery such as fewer complications, fewer transfusions and shorter LOS, the authors request that more prospective studies are undertaken in order to assess its comparative effectiveness compared to conventional surgical approaches.

Two such comparative evaluations include those of Heemskerk, Bouvy and Baeten (2014) and Tandogdu et al. (2015). Heemskerk et al. (2014) consider the clinical benefits and costs of the use of robot-assisted surgery. They conclude that while the additional costs are well established (they estimate a premium of €600 and €3,000 per procedure compared with conventional laparoscopy) the clinical evidence remains immature. In particular they argue that there is a lack of reported adequately powered, blinded, RCTs. Tandogdu et al. (2015) reach a similar conclusion in their systematic review of cost effectiveness studies of robot assisted laparoscopic surgery. They identified 47 economic analyses, which included six full evaluations (costs compared to benefits) and 41 cost analyses, across a range of procedures from prostatectomy to hysterectomy to myotomy and cholecystectomy comparing robot-assisted laparoscopic surgery to either laparoscopic or open surgery. In all instances robot assisted surgery had higher costs than its comparator. The authors correlated the limited number of economic evaluations (12% of their sample) with a limited evidence base, although in the studies with an appropriate time horizon (ten years to capture all costs and benefits) a similar incremental cost effectiveness ratio (cost per quality adjusted life year) was reported (€26,647 (Flattery et al., 2012); £18,329 (Close et al., 2013)) which would be deemed acceptable to a decision maker given standard cost effectiveness thresholds.

It is important to note that cost-effectiveness of robotic-assisted MAS (and indeed any intervention) critically depends on what you are comparing it with, it should be the intervention it will be displacing. The extent of improvement in clinical effectiveness and

improved recovery is likely to be less when comparing robot-assisted MAS with conventional MAS (as opposed to open surgery), thus making its cost-effectiveness more difficult to establish. The appropriateness of comparator is discussed further later in the report.

2.4.2. Surgeon views, beliefs and attitudes

A survey of US surgeons identified three main barriers to the uptake of robotics: perceived ease of use and complexity, perceived usefulness, and perceived “behavioral control” (autonomy) (BenMessaoud, Kharrazi and MacDorman, 2011). Barbash and Glied (2010) add a different perspective. They postulate that the fragmented nature of the healthcare system means that hospitals are forced to compete with each other to attract surgeons and patients and therefore find it “difficult to resist surgeon’s preferences” and as such invest in robotic surgery despite the lack of cost-effectiveness evidence.

In their analysis of trends in the use of robotics for three procedures (Marcus et al., 2017) (discussed above) conclude that, although costs are a barrier, they do not themselves explain the different rates of diffusion. They broadly identify surgeon and patient characteristics as reasonable factors warranting further investigation. They argue that surgeons may also be reluctant to use robotics that have a large operating room footprint, a long setup time, lack haptic feedback, and risk malfunction or failure.

2.5. National guidelines regarding laparoscopic surgery

Finally, to give further clinical context to the MAS uptake and barriers debate, the National Institute for Health and Care Excellence (NICE) have produced a number of recommendations on the use of laparoscopic surgery for the three specific procedures under consideration. These include the following:

- TA107 Laparoscopic surgery for colorectal cancer – “Laparoscopic (including laparoscopically assisted) resection is recommended as an alternative to open resection for individuals with colorectal cancer in whom both laparoscopic and open surgery are considered suitable.” August 2006
- TA83 Laparoscopic surgery for inguinal hernia repair – “Laparoscopic surgery is recommended as one of the treatment options for the repair of inguinal hernia” January 2001
- IPG239 Laparoscopic techniques for hysterectomy – “Current evidence on the safety and efficacy of laparoscopic techniques for hysterectomy (including laparoscopically-assisted vaginal hysterectomy [LAVH], laparoscopic hysterectomy [LH], laparoscopic supracervical hysterectomy [LSH] and total laparoscopic hysterectomy [TLH]) appears adequate to support their use, provided that normal arrangements are in place for consent, audit and clinical governance” November 2007.

Note that the existence of positive NICE guidance should facilitate the use of, and reduce variation in uptake of, the recommended technology. Despite these recommendations, uptake of MAS remains varied across NHS Trusts and surgeons. The objective of the interviews, described in the following section, was to investigate why this is the case.

3. INTERVIEWS

The primary research question for this project is: What are the barriers to uptake of MAS in clinical practice?

The literature (described above) has established the relative merits of MAS versus open access surgery, thus we specifically ask: Given the benefits, why is MAS not utilised more widely? Whilst there is some evidence in the literature to support an assessment of the relevant issues, there is no comprehensive inquiry and analysis of the barriers, particularly in the context of the UK.

3.1. Method

Interviews with key stakeholders in England were undertaken between November 2017 and January 2018. The objective was to identify the barriers to MAS on the ground, both financial and clinical. In order to gain an in-depth understanding of a broad range of the relevant issues, we adopted a 'maximum variation purposive sampling' technique for the interviews.

Our sampling approach aimed to capture the perspectives and opinions of stakeholders with a broad range of insights, backgrounds, and roles in the uptake of MAS. We therefore sought a range of interviewees to encompass:

- Different roles in the undertaking or planning of surgery (surgeons across the specialty areas of interest, finance directors, and clinical leadership roles);
- Different types of Trusts (large, small, teaching, district generals), and;
- A range of 'adoption' level for MAS (acknowledging that the perspectives of low and high adopters are likely to be very different, and useful for unearthing the perceived or realised barriers to MAS).

The intention was to interview a heterogeneous sample of interviewees, in order to gain an insight into the various perspectives they might offer. Thematic analysis was undertaken whereby themes from each interviews were assessed in an iterative manner (akin to the constant comparative approach) (Coast, 2017). We undertook to carry out 12 interviews in the first instance, with the intention to re-assess the suitability of the sample size following the qualitative analysis of interview data. The ambition was to achieve "saturation", i.e. where no new themes emerge upon further interviews (to be differentiated from "consensus", for which this study design is not appropriate).

High/low uptake Trusts were identified using England Hospital Episode Statistics data, specifically Trust level elective activity episodes for 2015/16. Specific colorectal, gynecological and abdominal procedures were identified using OPCS codes. These codes were also used to identify whether the procedure was open or minimal access. The rates of minimal access were then calculated. Trusts were then ranked by average rates of minimal access for the basket of procedures. Potential candidates for interview were identified from Trusts that were targeted due to their high/low uptake of MAS. Individual interviewees were identified based on their job role: clinical or finance. Consultant surgeons within the specialty procedures examined in the literature review were purposely targeted, but other clinically trained professionals were also approached, for example where the individual had a key role in MAS delivery or adoption in their respective hospital.

Contact was first initiated via email, and followed up by telephone where relevant. An honorarium of £250 was offered for participating in the research. In the event of a poor response rate, we proposed to expand our initial list of target Trusts (the highest three adopters and lowest three adopters of MAS).

Interviews were conducted over the telephone, lasting around an hour in duration, and followed a semi-structured format. The semi-structured interview guide can be found in

Appendix 2 and was informed by the literature review. The interview guide was shared with participants in advance, but no preparation was required. Questions were not stuck to rigidly, and the focus differed according to the questions' relevance to the role and experience of the interviewee.

Where possible, two researchers attended each interview. Based on the detailed notes of both researchers, the qualitative data from each interview was documented and collated. The researchers then conducted a thematic analysis of the qualitative interview data iteratively. This is a method by which patterns (themes) within the data can be identified, analysed and reported, allowing the researcher to both organise data and interpret the research topic. Themes (and sub-themes) relate to patterns identified in the data which provide a significant insight (Coast, 2017).

3.2. Summary findings

In total we interviewed 12 individuals, covering a broad range of roles and specialties. In the latter interviews no new "themes" relating to the barriers to MAS were emerging, and therefore the sample size was not expanded. The characteristics of the 12 interviewees and the code with which they are referred to in the Results are presented in Table 1.

The main insights that arose from our qualitative analysis of interview data are summarised in the next section under five main themes: Clinical- and cost-effectiveness; Roles of the key stakeholders in MAS; Training; Understanding the context for service delivery; and Robotic-assisted MAS. Analysis is presented under various sub-themes, a summary of which are presented in Appendix 3. Note that there is overlap in some sub-themes such that the qualitative evidence which are relevant for more than one theme are referenced on more than one occasion. Under each main theme, we provide a high-level summary (in italics) of the findings.

Table 1. Interview participants' characteristics

Code	Role (specialty where relevant)	Undertakes private practice?	NHS Trust – type ^A	NHS Trust – high or low adopter MAS ^B
FD1	Chief Financial Officer	n/a	Acute teaching trust	High
FD2	Director of Finance	n/a	Acute teaching trust	Low
DS	Director of Strategy (executive board of directors, previously chief operating officer and commissioning role)	n/a	Medium acute trust	High
CMO	Chief Medical Officer (also Gynaecology and Obstetrics Surgeon)	Yes	Large acute trust	High
CS1	Consultant surgeon (and Divisional Clinical Director, head and neck oncology)	Yes	Acute teaching trust	High
CS2	Consultant surgeon (and lead clinician, gynaecological oncology)	Yes	Medium acute trust	High
CS3	Consultant surgeon (hernia and colorectal)	Yes	Medium acute trust	Low
CS4	Consultant surgeon (and clinical lead & course director in laparoscopy, Gynaecology)	No	Acute teaching trust	High
CS5	Consultant surgeon (colorectal)	Yes	Large acute trust	High (but medium/low for colorectal)
CS6	Consultant surgeon (and divisional director for women's and children's, obstetrics and gynaecology)	Yes	Acute teaching trust	Low
CS7	Consultant surgeon (gynaecology)	Yes	Acute teaching trust	Low/medium (but medium/ high for hysterectomy)
CS8	Consultant surgeon (and lead clinician, upper GI and hernia)	Yes	Large acute trust	Low/medium

^A Source: <http://www.nrls.npsa.nhs.uk/patient-safety-data/organisation-patient-safety-incident-reports/organisation-categories/>

^B Source: OHE Analysis of Hospital Episode Statistics (HES) data, provided by Harvey Walsh (licensed by NHS Digital under data sharing agreement DARS-NIC-05934-M7V9K-v3.2.) of utilization of MAS versus open-access across procedures: hysterectomy, inguinal hernia, ventral/incisional hernia, rectal excision.

FD: Finance Director; DS: Director of Strategy; CMO: Chief medical officer; CS: Consultant surgeon

3.3. Clinical- and cost-effectiveness of MAS

There was general buy-in to the clinical evidence-base for MAS, which was noted in particular to be associated with improved recovery and patient satisfaction. However, clinical considerations differ by procedure.

Generally there was recognition of the trade-off, identified in the literature, between longer operating time and greater costs associated with MAS, offset by savings from a reduction in hospital length of stay due to improved recovery. Improved recovery resulting from MAS has been shown to reduce hospital facility requirements (beds, staffing and costs), especially important for hospitals with constrained estate and tight financial resourcing. Furthermore, MAS operating times are becoming shorter and for

some procedures are comparable to open procedures. However, the impact of MAS on reduced length of stay is procedure-specific, and characterised by the nature of recovery (whether mainly from the incision or the consequences of the procedure itself). Therefore, this needs to be considered on a procedure-specific basis.

Budget silos are argued to foster inefficient decision-making. Financial and systems oversight, and a reduction in "silo-thinking", are required to enable the decisions to be made that are right for the Trust.

3.3.1. Clinical-effectiveness

Interviewees were asked about their views on the clinical-effectiveness of MAS. Whilst the clinical-effectiveness and safety considerations of MAS differs by procedure, it was considered by most interviewees that the evidence-base supporting MAS is, in general, strong. Indeed, there was some suggestion that the published evidence base does not yet capture all the longer term benefits of MAS. However, interviewees were careful to note that MAS and its suitability should be considered on a case-by-case basis, and considerations differ substantially by specialty.

Outcomes

The potential benefits of MAS identified in the literature were corroborated by clinicians, noting in particular the faster recovery and associated reduced length of stay, increased patient satisfaction and quality of experience, reduced wound infections, as well as the associated reduction in morbidity and scarring (an element which is often not captured in clinical studies). In general, it was considered that, for patients undergoing MAS versus open-access surgery, outcomes were at least as good (often better), certain complications were reduced, and recovery was much quicker. Beyond the procedure and immediate recovery, longer-term benefits are also said to have been established (CS4). As a result, the use of MAS has been and continues to be extended into more complex cases.

However, there were some differences of opinion. Whereas several interviewees were very clear on the benefits of MAS over open-access (CS2, CS3, CS4, CS7, CS8, DS), others were explicit about the procedures for which they believe an open-access approach is still valid, or even preferable (CS1, CS5).

Several interviewees highlighted that disease outcomes were the key driver in decision-making. Where outcomes are demonstrated to be similar, then recovery time and procedural complications become the important factors in driving choice around route of access. However, if outcomes are even marginally worse using MAS this would far outweigh the benefits of shorter recovery time or other benefits often attributed to MAS. One colorectal surgeon (CS5) believes this to be the case for colorectal surgery, and as a result prefers to conduct open-access surgery. It was noted by CS5 that MAS is the best approach for certain procedures, but that its benefit is characterised by the nature of recovery (whether this is due to the incision or the consequences of the procedure itself).

Safety

The safety of a surgical procedure is of paramount importance, and several interviewees cited reductions in complications and infections as a primary motivator for the adoption of MAS (CS2, CS3, CS4, DS, CMO). For hernias, CS1 noted that MAS might be associated with higher risk of complications for some clinicians. CS5 shared concerns

regarding the risk (even though small) of iatrogenic injuries which is unique to MAS in colorectal cancer surgery.

Contraindications

Certain patient characteristics contraindicate the utilisation of MAS. Specific factors discussed included high BMI, respiratory comorbidities, and whether the patient has already undergone surgery. However, whilst MAS may be difficult to perform in patients with high BMI, its benefits may be even greater for those patients, as risk of complications such as infections are reduced (CS2, CS7, CMO). This is confirmed in the literature review.

Belief in the evidence base

Most interviewees were keen to comment on the “robust evidence base” for MAS, outlining all of the benefits to patients which are referenced above and in the literature review. However, outcomes and evidence must be considered by specific sub-specialty, as the clinical considerations are very different.

One clinician (CS2) who did believe in the evidence-base for MAS, cited one NICE clinical guideline (for “heavy menstrual bleeding”) as a barrier to the development of MAS. Because of the nature of the evidence hierarchy adopted in guideline generation, older techniques are identified and recommended. The clinician felt that these did not represent current best practice but that the evidence base for newer techniques could not be established.

One clinician (CS5) referenced some evidence demonstrating poorer outcomes associated with laparoscopic colorectal resection, and therefore would not consider employing that technique.

3.3.2. Cost effectiveness

Trade-off between short-term costs and longer-term gains?

Nearly all interviewees regardless of role or sub-specialty discussed the benefits of MAS in relation to a trade-off between longer time in the theatre, versus faster recovery and reduced length of stay in hospital. Manifestation of the reduced length of stay was highlighted in a number of interviews, highlighting the reduction in beds, staffing, and costs that have arisen from their move to MAS.

Cost-effectiveness arguments were well understood by all participants. However, the implementation of these in practice differed. The impact of MAS on length of stay may be limited for very simple procedures where even open surgery is conducted as a day case (CS1, CS8), and for very complex procedures where the nature of recovery is dominated by the procedure itself rather than the incision (CS5). For colorectal resection, for example, the nature of the incision is not the dominant factor for post-operative recovery, but rather it is the return of gut function. According to CS5, this means that the benefits of MAS are less in colorectal surgery. However, one surgeon was keen to point out that, even for those complex cancer procedures where length of stay is similar for open surgery and MAS, the improvement in patient experience and recovery in hospital was a critical factor (CS8). Similarly, for simple procedures such as hernia repair, where both MAS and open surgery could be conducted as a day case, the improved recovery at home and quicker return to work and resumption of normal activities are extremely important (CS8).

It should be noted that impact on length of stay in hospital should be considered alongside re-admission rates. One surgeon (CS8) described an “enhanced recovery program” that was implemented in their hospital to reduce length of stay following cancer resection, which they halted as they found that re-admission rates rose.

The longer theatre time associated with MAS versus open-access surgery was not recognised by all interviewees. Where surgeons have had the opportunity to specialise, the average procedure time for MAS has reduced, in some cases being considered the same (CMO) or even becoming quicker than open access (CS1, CS2, CS4). This depends on both the experience of the surgeon, and also the nature of the surgery; in more complex surgery such as colorectal cancer, MAS was noted to take significantly longer (by around 2 hours [CS3]). Therefore, to the extent that theatre-time acts as a barrier to the adoption of MAS, this is more pronounced in more complex surgery such as unilateral hernias and major bowel resection, where the time differential between performing open or MAS is the greatest. One surgeon pointed out that the increased costs associated with longer time in theatre should be offset by the reduction costs associated with dressings, wound care, and antibiotics, which are greater for open surgery (CS8).

Whilst a major advantage of MAS is thought to be the reduction in associated length of stay, and the conversion of more procedures to day cases, the physical estate and workforce constraints were noted by one interviewee to place a ceiling on this benefit (to the extent, in their case, that the benefit cannot be realised) (DS). In this Trust pressures on physical estate, specifically the requirement to maintain bed capacity for emergency inpatient activity pressures, mean that it would be rational to increase the rate of patients treated using MAS and as day cases. But because they are “at capacity” for day case procedures, caused mainly by shortages in support staff, instead these patients remain on the waiting list.

“Silo thinking”

Clinicians cited the potential for “silo thinking” in NHS Trusts to act as a barrier for MAS, by impeding the necessary oversight required to balance the costs and savings associated with a move to MAS, as well as the service planning required across departments.

The resourcing of the theatre, anaesthetics, and the inpatient ward all accrue to different budgets. Where planning around staff and resource is on the basis of one of these departments only, decisions may be made that are inefficient for the system as a whole. CS6 described how silo management inhibited the development of theatre staff in line with requirements of the clinical groups, thereby restricting MAS for more advanced procedures where theatre staff are less able to support.

Several surgeons and directors noted that the presence of a clinician or active team with financial oversight and responsibility for various services minimised the issue of budget silos, whilst others saw the “compartmentalised” nature of the NHS as a significant factor reducing the level of MAS undertaken in their hospitals. In particular, one surgeon noted that short-term targets are a key driver in day-to-day decision-making. For example, where the threat of not meeting cancer targets was at stake, any trade-off between theatre time and length of stay (he suggest two hours extra theatre time versus three days saved in hospital stay) “goes out of the window”, and he is therefore compelled to select an open-access route to surgery simply in order to clear the waiting list more

quickly (CS3). Most other interviewees did not recognise that there was a pressure from management to meet targets where the consequence would be a sub-optimal procedure.

This perceived silo thinking, whereby it is thought that the necessary oversight required to balance short-run costs (longer theatre time) with greater long-run gains (improved recovery and shorter length of stay) is absent, is in sharp contrast to the impression given by the finance directors who were acutely aware of the trade-off and placing this at the forefront of decision-making. We speculate that any finance director would highlight the importance of this tradeoff which is well understood in theory, and that actually the issue is one of implementation. The financial oversight function intended to overcome silo budgeting may breakdown where the pressure of short-term targets and conflicting objectives in the running of day-to-day business are the main drivers in decision-making. This view was corroborated by several surgeons who highlighted the immediate financial pressures which drive short-sighted decision-making.

3.4. Roles of the key stakeholders in MAS

A core part of the planning process for considering investment opportunities relating to MAS is through the generation of a 'business case', a process driven by clinicians and evaluated by a team with strategic and financial oversight who consider the return on investment. There were different views as to whether this mechanism for financial planning supported investment in equipment to promote MAS. There appeared to be a risk that some MAS equipment might not be costly enough to be considered formally by management, but too expensive to be covered by contingency capital budgets. In this case, it is important to ensure that decisions are not made on the basis of cost alone, at the expense of quality.

There was an indication that commissioners were becoming a more important stakeholder in the planning process and hence in their ability to influence uptake. The tariff system used in England had the potential to encourage uptake, notably through the use of "best practice" tariffs, which provide a price uplift in order to reduce variation and incentivise best practice. This can encourage monitoring and systems changes required to encourage MAS, but has so far only been implemented in the context of day-case hernia repair. Examples of other commissioning arrangements that could promote MAS were provided, such as Commissioning for Quality and Innovation (CQUIN) payments for reducing rates of abdominal hysterectomies.

It is clear that individual surgeon preferences play a critical role in the uptake of MAS in any given hospital. The nature of their core medical training, and how long ago this was (with older consultants often more comfortable with open surgery) has a key influence on willingness or ability to conduct MAS. However, where buy-in for MAS is achieved, referral of cases to colleagues can mitigate this issue. The importance of a "clinical champion" to drive change and fight for investments to support MAS was clear.

The extent of the impact of patient preferences on MAS uptake are procedure specific, being more significant for simpler procedures such as hernia repair. However, beyond procedure-specific considerations, the importance of a 'cultural' change to support MAS is clear, which transcends the role of hospital, surgeon and patient individually.

3.4.1. Role of the hospital and commissioner

Considering investment opportunities: evaluating the "business case"

The infrastructure available in a Trust is a significant determinant for the level of MAS undertaken. Increasing the levels of MAS will require both initial capital investment and

ongoing capital expenditure for replacement and consumables. Greater uptake is bounded by both financial and clinical considerations. Almost all interviewees characterised this planning and investment process in the context of developing a business case.

Financial and strategic interviewees emphasised that the start of the process of business planning was initially a process of clinical prioritisation within departments. Generally there was a formal, clinician led process undertaken prior to development of the financial case. The role of the clinician is discussed below.

When considering investment decisions for equipment required to support MAS, factors include initial capital outlay, cost of capital and ongoing costs. The finance director of a large hospital (FD1) noted that the relatively low level of funding required to support ongoing MAS in general was such that it would rarely come across his desk, and instead be covered by the budget set aside for small equipment purchase and replacement, which is managed by a small sub-committee of doctors. However, according to another finance director (FD2), there may be a risk that intermediate size capital projects are "lost in the middle" – a situation described by FD2 as potentially relevant for equipment required by MAS; whereas large capital investments are considered through a formal process, and smaller projects through a contingency capital budget, there may be instances where capital equipment is too expensive to be covered by contingency capital budgets, but too small to warrant specific consideration at a management level. There is a risk that such medium investments are not prioritised, or are subject to delays in funding. On the other hand, the director of strategy (DS) said that almost all capital equipment for MAS meets the threshold for formal consideration at trust level.

Most surgeon participants described their experiences in developing a business case, which must capture the full spectrum of costs and benefits associated with the proposed investment. One interviewee noted that previous "successful" business cases pave the way for creating subsequent cases, for example where the case for and evidence relating to reducing length of stay has already been established (CS2). One director noted that the skill at business cases tends to be low, and that they "often get knocked back" because the return on investment case is not well made (DS).

There can be a trade-off between cost and clinical-effectiveness of the equipment necessary to support MAS (CS2). Two clinicians (CS5, CS4) noted that there has been an emphasis on securing the cheapest options when making decisions on purchasing smaller capital items and consumables. For one this did not override clinical considerations and was simply a consequence of the business case planning process. One clinician (CS3) in a low use MAS hospital cited a specific example where the decision to purchase a lower cost and clinically inferior item of capital equipment has resulted in a colleague ceasing to undertake specific MAS procedures.

One particular aspect of financial planning that was raised was the tariffs (by which hospitals are paid for the activities they undertake; activities are defined by their healthcare resource group, HRG). When finance directors consider the business case for investing in capital equipment, they calculate the expected returns over the life of the capital. This is based on current NHS England national tariffs and expectations regarding future tariffs. Tariffs can go up and down which can make financial planning and investment decisions difficult. This uncertainty becomes especially important where the margins of return in the business case are tight. Both finance directors emphasised the

uncertainty created by unstable tariffs, and the difficulty created for planning and investment decisions.

One interviewee (DS) operated in a system of a fixed income ("block") contracts with their main commissioners. Each commissioner and Trust agrees a total funding schedule for the year calculated for an expected level of emergency and elective service delivery. Therefore, a cost per case calculation of revenue does not form part of a business case for this Trust (there are no revenue benefits from moving patients through more quickly). Whilst this could be perceived as a barrier (or rather a lack of incentive) for MAS, it was argued that this was not the case: instead, proposals and business cases should demonstrate improvement in service quality and be cost neutral or be aligned with the Trust's overall strategic direction. So there are incentives to adopt MAS, but this is based on service (better performance) and quality (better patient experience) improvements within a funding and service framework agreed with commissioners. Therefore, block contracts were not seen to be a major barrier (DS). However one finance director, who currently operates under the HRG system (payment by volume), suggested that a move toward block contracts will change the dynamic of business cases for investment in changes to service provision, and that this could become more complicated (FD1).

Reimbursement of MAS

Best practice tariffs are seen by some as an important driver for procedures such as MAS. Best practice tariffs help the NHS improve quality by reducing unexplained variation in order to universalise best practice, by incentivising high quality and cost-effective care. The price 'uplift' (what commissioners will pay the hospital for carrying out the procedure) is calculated to cover the costs of undertaking the best practice plus an incentive for providers to shift from usual care to best practice (NHS England, 2016). They can thereby provide a financial incentive to provide changes in service provision that are of important clinical benefit, and create the mechanism for financial teams within hospitals to investigate and enable the changes required to implement these best practices. Although these tariffs were seen as a useful mechanism it was questioned whether current best practice tariffs provide specific incentives for increasing the use of MAS in particular; one finance director (FD1) indicated that they did, whilst the other (FD2) suggested that they had limited applicability for MAS, and two consultant gynaecologists (CS2, CS4) indicated that these were not available in gynaecology.

Upon evaluating the procedures that attract a best practice tariff, the tariffs under "Day-case procedures" – defined as an admission where the patient is discharged before midnight – may have strong relevance to certain procedures that can be performed via minimal access. Best practice tariffs have been applied to 34 specified procedures, the majority of which relate to surgical procedures (NHS England and NHS Improvement, 2016). The list includes a best practice tariff for day-case hernia repair. It was explained (by FD1, CS3 and CS6) that this financial incentive can support re-organisation required to attract the tariff, e.g. moving surgery lists to the morning instead of the afternoon. It was noted by CS3 that, in his individual's experience, this was better implemented in the private than the public sector. It was noted by the director of strategy (DS) that best practice tariffs do have an impact in the context of a block contract as well, and are calculated on an annualised basis.

In 2009, NHS England introduced a system to make a proportion of healthcare providers' income conditional on demonstrating certain improvements and innovation:

Commissioning for Quality and Innovation (CQUIN) payments (NHS England, 2018). One surgeon (CS2) cited a local CQUIN that encouraged a reduction in abdominal hysterectomies and supported investment in the MAS service, which had the impact of reducing rates of abdominal hysterectomies.

There is general consensus that clinical decisions are made on a case by case basis. Whilst there are accepted models of 'good practice' that can be driven by hospital policy, and incentives in place to encourage MAS where appropriate, the decision around surgical technique will always be with the surgeon. Financial directors were particularly keen to emphasise this point.

3.4.2. Role of the surgeon

Surgeon preferences and characteristics

Surgeon preferences play a major role in the uptake of MAS. The CMO described the main barrier to adoption of MAS to be staff buy-in. It was noted by many that the age of the surgeon – reflecting when they were trained – had important implications for choice in surgical technique (CS1, CS3, CS4, CS7, CS8). Surgeons have a tendency to "stick to what they are comfortable with" (CMO). Whereas those trained after the mid-90s were all trained in laparoscopic techniques, there is a greater preference for more "old-fashioned" open-access techniques among surgeons that were trained earlier. The landscape is therefore evolving, as those preferring more old-fashioned (open) techniques approach retirement age. In cases where senior staff with a preference for open-access have an important influence on service planning, this could act as a barrier to MAS (CS3). The related issue of referring cases to colleagues is discussed below and is a way of reducing the potential impact of this factor on overall adoption by the Trust.

As well as their training and experience, major drivers around surgeon preferences are their understanding of the evidence base, past experience and culture of the hospital. One surgeon noted the desire by some clinicians to use the latest gadgets (CM5), thus driving the uptake on new equipment. The degree of difficulty of MAS for some procedures also influences preference (see also training, below), as well as the impetus to invest in newer equipment. One surgeon noted that investments in capital to support MAS had been undertaken, supporting the refurbishment of two theatres, which has facilitated safer delivery of surgery in a way that is more ergonomic for the clinician as well (CS1). Repetitive neck strain injury has reduced as a result. It was suggested that robotics are the next stage in making practice safer and easier for the surgeon.

Importance of a clinical "champion"

According to both finance directors (FD1 and FD2), clinicians have critical input in financial planning activities, playing the lead role in clinical transformation plans, and making clinical and business cases for investments which form the basis of financial planning for the next year. We were provided with several examples of clinical leads being involved in developing and presenting the clinical and business case for investments in the infrastructure required to deliver (better) MAS, e.g. refurbishing theatres to deliver MAS more safely and ergonomically (CS1).

Transformations in care provision are fostered through the enthusiasm of a clinical "champion". One finance director (FD1) emphasised that the enthusiasm of the clinical champion was absolutely vital for a project to "have legs", and that they drive the development of a business case. The work of the champion is the "entry ticket", and transformations are not introduced simply because they are cost saving. Consequently,

the interviewees who appeared to be clinical champions themselves and who worked in centres of clinical excellence for MAS, suggested that commissioning, reimbursement, and investment matters were not an issue, and did not pose barriers (e.g. CS4).

Conversely, where a clinical "champion" does not exist, the necessary enthusiasm to drive change and secure investment in innovation may pose a barrier to MAS. One surgeon noted that he simply did not have the time to make the case for investment in better equipment that could drive MAS forward, due to constraints on his time and other priorities (CS3).

Referring cases to colleagues

Even in units where an MAS approach dominates, there are usually individual surgeons within a clinical unit who do not have the requisite training or experience in MAS, or simply prefer open surgery. As commented by the CMO, "Clinicians can be quite protective of their own work and what they do, and so if they don't have those skills, then the patient doesn't get that choice. They aren't given the option". However, this practice was noted by the CMO and several others to be diminishing rapidly. It should be noted that the 'Montgomery ruling' of 2015 should support the requirement by clinicians to collect informed consent from patients by discussing the risks and options available. CS7 noted that "professional pride is a thing of the past". Where a particular surgeon does not have the skills to undertake MAS and they perceive it to be the best option for the patient, they will readily refer the case to a colleague who does have those skills, or even call in colleagues during operations to avoid converting to open in cases where they are experiencing difficulties with MAS (CS8). In this way, individual preferences or skills need not represent a barrier to increasing use of MAS for a unit overall. To achieve this there has to be a climate of recognition of the benefits of MAS within the unit. CS4 described the process where this was achieved, starting with a data collection process on activity and outcomes for an eight year period. This was then used to demonstrate that, for a number of procedures, MAS was associated with improved outcomes and that MAS operations were being delivered by a subgroup of colleagues. Therefore patients identified as suitable candidates for MAS should be referred to these colleagues.

As well as referral between colleagues, various interviewees in centres advanced in MAS receive referrals from other Trusts for more complex laparoscopic cases (CS2, CS4, CMO, CS7). This may have implications for the development and maintenance of MAS skills as this is associated with volumes of activity undertaken.

3.4.3. Role of the patient

Whilst some participants suggested that patients have little input into decision-making on surgical route, being mainly clinician driven (CS2, DS, CS5), the role of the patient in decision-making is generally considered to be rising. However, the extent to which patients "have a say" in their mode of treatment varies greatly by condition. Whereas for certain simple procedures, like hernias, the view of the patient and their preference for MAS may have a significant role in the option selected, for other more serious procedures the surgeon's recommendations are likely to override anything else. This is the case particularly for cancer surgery where variation between MAS and open are moot in the context of wider clinical considerations, and where the patient's recovery is not dominated by the size of the incision (CS3, CS5, CS6, CS8).

The CMO described the patient as having the leading role in driving change, especially so in the new age of information. Explaining to the patients the important benefits of MAS

means that they are empowered to “ask the right questions” which, in the case of MAS, should be “Why am I not being offered that?” (CMO); clinicians are then forced to respond. Whereas over the last few years there has been emphasis on organising staff to deliver MAS, and organising services to make it possible, in the future it will be the patients asking the questions and driving the change.

3.4.4. A ‘cultural’ change

An aspect that many interviewees referred to, beyond the individual roles of the hospital, the surgeon, and the patient, was the “culture change” required for the implementation of MAS. Participants talked of the time taken to change attitudes. One surgeon described the nine year period over which MAS was introduced into their gynaecology department, driven primarily by evaluating the trust-level evidence of performance and outcomes against national data, and getting buy-in from colleagues based on this evidence-base (CS2). The CMO described the importance of bringing all clinical staff on board (theatre staff and ward staff) and described activities that were set in motion early on in his trust, to highlight best practice, break down barriers, and provide opportunities to learn and develop skills on site rather than through ad-hoc training opportunities. Additionally, if a level of expectation is driven by patients then service providers have to keep up.

Several interviewees noted the manifestation of this cultural change via the appointments of new staff (in some cases themselves) specifically trained in MAS, who could cascade their skills to colleagues (CS2, CS4, CMO, CS7, CS8). According to the CMO, these appointments in his Trust were made as part of a long-term strategy to support the development and expansion of MAS services; the interviewee referred to the importance of a “critical mass” of surgeons trained in MAS, and the buy-in at board level. Notably this view is at odds with the colorectal surgeon from the same Trust (CS5), who said that there was “no grand plan” for increasing the uptake of MAS within their Trust, suggesting information exchange is an issue. The increased willingness of surgical staff to refer cases to colleagues with MAS skills where necessary was also noted by several interviewees to be an indication of a cultural change. Support for investments to facilitate and drive MAS were also noted to result from this cultural change (CS2, CS4, CMO).

3.5. Training

Generally clinicians felt that opportunities for formal training were numerous. Various factors were identified explaining why these opportunities may not be taken-up, including motivation and the availability of funding, with many surgeons funding their own development in MAS. The importance of ongoing exposure to MAS to maintain and develop the relevant skills was recognised.

3.5.1. Availability of training opportunities

The basic level of MAS training offered to trainee surgeons was noted to not be sufficiently specialised to suitably prepare surgeons to undertake MAS beyond basic procedures, and in order to keep up with evolving technology and techniques, more and better trained staff are required (DS, CS2, CS4, CS7, CS8) (though CS5 disagreed with this, noting all trainees will have the baseline MAS skills, “which are transferrable” and which should “at the end of the day be exactly the same”).

The availability of more advanced training opportunities was not generally seen as a significant barrier for MAS in England, with nearly all interviewees stating that there were many courses and opportunities available, and that these had expanded over time.

Several ongoing training initiatives were cited, including the role played by the Royal College of Surgeons and the importance of compulsory simulation training (CS1). The British Society for Gynaecological Endoscopy was also cited as important in the provision of training opportunities, as well as bursaries for training (CS2, CS4, CS6). Several interviewees were involved in the delivery of training themselves.

As noted by a finance director (FD1), the issue of the content of surgical training for MAS is not necessarily monitored by the Trust board; budgets for training are devolved to the care groups. The other finance director (FD2) noted that although MAS training was not specifically monitored, satisfaction with the quality of training given was benchmarked.

3.5.2. Uptake of training

Generally it was perceived that there was a good availability of training opportunities. The director of strategy noted that the barrier was not the capacity to be able to provide the training, but the supply of trainees to participate and adopt more advanced procedure-specific skills. This sentiment was echoed by the CMO, who described that the key issue was not the ability to provide training, but creating the demand: if the demand is there, the training will happen.

A lack of suitably-trained consultants in MAS may be to do, not with the availability of training, but the uptake of those training opportunities. Uptake of training opportunities was noted to be largely down to the individual surgeon. Factors include motivation, lack of time, and also a lack of resources. Several clinicians raised the issue of self-funding for training (CS5, CS7, CS8), due to either insufficient support from hospital training budgets, or difficulty in accessing (or limited awareness of) other funding opportunities and bursaries. CS6 described that access to training is more formally controlled than in the past, and must support the context and requirements of the department. It was noted that in order to get the best, hands-on laparoscopic training, it was often necessary to go abroad, at a high cost which surpassed the budgets generally offered to surgeons for training. Restriction of training opportunities to those with the means to pay for it themselves may therefore be considered a barrier to training and therefore to MAS.

3.5.3. Patient throughput and the learning curve

The impact of the 'learning curve' – whereby, as surgeons become more accustomed to a technique, they become much better and more efficient at delivering it – has already been mentioned in relation to its impact on reducing the theatre time required to deliver MAS (considered traditionally to be longer than open-access).

A key consideration is the ability for surgeons to move along this learning curve, by being given sufficient opportunity to undertake and thereby practice their skills in MAS. This was noted by CS1, who proposed a potential link between volume of surgery and rates of uptake of MAS. In units where volume is low, it may be that there is insufficient opportunity for surgeons learn and implement MAS (CS3). Some hospitals are addressing this by providing weekend lists for specific surgeons in order to undertake MAS under supervision, and cascade training in this way (CS6). The provision by hospitals to match new consultants with more experienced surgeons was emphasised by several interviewees, in order to allow hands-on training for more junior members of staff.

The way in which clinical departments are organised may impact on the ability for surgeons gain enough experience to deliver MAS and to move along the learning curve. CS7 discussed this in relation to obstetrics and gynaecology, whereby obstetrics is often

seen to take priority for trainees, who are thereby unable to gain enough experience in gynecological procedures unless they go down the sub-specialty route.

As well as volume, access to a mix of cases was noted to be important for maintain skills in MAS (CS2, CS4).

As well as surgeon skill which can improve with practice, it is important to note that there is high variability in outcomes between MAS patients because of specific patient characteristics. In recognition of this, the Quality indicator for Surgical performance in Minimally invasive surgery (QUSUM) is a web-based application that can compare clinical outcomes and quality assessment, whilst correcting for case-mix. One surgeon (CS6) described the use of this in their hospital to assess practice.

3.6. Understanding the context for service delivery

Whilst MAS has generally been on an upward trajectory, the pace has slowed or even reversed in some specialties. The financial constraints under which the NHS increasingly operates may be a contributor to this landscape, creating strong capital constraints for hospitals (for example, necessitating return on investments of capital equipment within 12 months, and for projects to be cost-neutral). Workforce capacity was noted to be a limiting factor to MAS, with development in MAS techniques outpacing the capacity and training of staff to deliver them. Constrained estate should be seen as a motivator for MAS, which can release bed space by reducing in-hospital recovery time. Most interviewees reported that the issues facing private practice were broadly similar to the NHS. Differences identified were the more significant role of patient preferences in the private sector, but a reduced tendency to refer cases to colleagues (thus placing greater emphasis on the skill set of the individual surgeon). In addition, health literacy and baseline level of health of private patients may be higher, and clinicians may have greater autonomy to choose their preferred equipment. However, given the smaller throughput of patients in private practice, amortising the cost of large ticket items may make high cost investments problematic.

3.6.1. Awareness of level of adoption

In setting up interviews, the level of adoption of MAS relative to open-access surgery in relation to three specific procedures – ventral and incisional hernias, hysterectomy, and lower anterior resection – was assessed, in order to ascertain whether the Trust as a whole (rather than the clinician specifically) was a relatively high or low adopter of MAS. Most interviewees from 'high adopter' Trusts expressed that the relative level of adoption by their trust of MAS (relatively high) resonated. The exception was a colorectal surgeon from a high-adopter trust (CS5), who believed their trust would be a lower-adopter (although for colorectal surgery specifically, the Trust has a medium/low uptake of MAS). It is interesting to note that CS5, who believed utilisation of MAS in his own discipline as well as other disciplines across the Trust was relatively low, was from the same Trust as the CMO who was one of the most enthusiastic and optimistic interviewees about MAS uptake. Similarly, some surgeons from relatively low-adopter trusts expressed surprise that this was the case. One noted that there was a potential for data to be influenced by the fact they are a specialist centre they might receive a high level of referrals, whose nature are more complex and therefore are more likely to require open surgery (CS7). It was apparent, therefore, that at a surgeon-level, their perceptions about practice in their trusts are influenced by their own practice (i.e. their preference for MAS or lack thereof). However, this may reflect the fact that our data are at Trust rather than hospital level.

3.6.2. Trends in MAS over time

All but two of the interviewees noted the rising trend in MAS, commensurate with the greater understanding of its benefits to patients and the NHS. One interviewee noted they actually had trouble finding the surgeons with the skills to do certain complex cases which require an open approach, given the broad implementation of MAS (CMO). However, some noted that, in their own experience, the proportion of surgery undertaken through minimal access was actually declining: both were colorectal surgeons. The reasons cited were financial / policy-related (CS3) and the emerging evidence-base (CS5). For CS3, the principal reason for the suggested declining utilisation of MAS in colorectal surgery is the pressure from waiting lists. For CS5, a perceived decline in colorectal MAS was due to an emerging evidence base describing poorer outcomes associated with MAS for colorectal cancer (see 'belief in evidence case' under previous theme).

The director of strategy (DS) outlined four main reasons for the slowdown in (but not reversal of) uptake in their Trust: (1) in most surgical disciplines MAS is now an embedded approach (i.e. "the early wins have been made"); (2) the degree of specialised training required for the most complex procedures; (3) capital constraints, and (4) day case capacity, primarily due to shortages in workforce.

Initiatives to reduce waiting lists

Given the increased time associated with delivering MAS compared with open colorectal surgery, and the limited theatre availability, the pressure of waiting lists and treatment targets means that some surgeons (as reported by CS3) feel pressure to undertake a higher volume of surgery by open means, thereby facilitating a higher throughput of patients (CS3) (this was noted briefly under the theme "silo thinking", above). Therefore, it was suggested that clinicians are driven toward greater use of open surgery simply in order to clear the lists and meet the immediate waiting list challenge. As a result, this surgeon did not perform MAS as much as he would like to (performing around 30% less MAS than he used to, due to this time constraint). The seasonal pressure and managing more or less urgent patients, in the context of list cancellations, adds to this pressure. Whereas in the past 'waiting list initiatives' allowed trusts to pay staff overtime in order to help undertake more cases, these are becoming less common (CS3).

This theatre-time constraint and waiting list pressure was denied by other interviewees, who were very clear that the decision on route of surgery is always a clinical decision, and that they would never undertake or encourage the use of open-access surgery just because of a "waiting list headache" (DS). Those in leadership roles were especially clear that the decision on route of surgery was always a clinical one (CS4, FD1, FD2, CMO).

UK versus international uptake

It was suggested that uptake in the UK is lower than in other countries (CS4). This was put into context by CS4 of training and job opportunities: compared with France, Germany and the US, rates of MAS in the UK are lower, which means that the UK is less likely to attract high-performing MAS surgeons as there are only a few centres of excellence.

Cultural differences may also play a role (CS1). For example, in South Korea scars are not acceptable and MAS uptake is much higher. In some clinical contexts the utilisation

of robots is necessary in order to increase MAS uptake, and so their under-provision in the UK is a barrier to MAS uptake (CS1).

'Drive'

Whilst the importance of "culture" and culture changes have already been discussed in relation to the uptake of MAS, the issue of drive or momentum was raised by some interviewees. Just as this can drive uptake, so too can it be reversed. For example, a colorectal surgeon (CS3) described how, 3 to 5 years ago, every conference in his specialty was dominated by discussions around laparoscopic surgery, which reflected the real "momentum" and "buzz" around the topic. This has apparently "disappeared" over the last two years. In hypothesising why this might be the case, he suggested that it may be that the "battle has been won" for the use of colorectal MAS, but the impact is that this reduced momentum may slow down the adoption of MAS. Another explanation may be the lack of innovation in laparoscopic colorectal surgery.

Commenting on the role of "momentum" in the initial drive in uptake of laparoscopic colorectal surgery, CS5 recalled the initial buzz and excitement around the procedure, which he believed may have been influenced by commercial interests and desire of surgeons to work with the latest gadgets, rather than being predicated on a solid evidence base. This momentum was propagated by the Department of Health, who issued a "diktat" through the LAPCO (laparoscopic colorectal surgery) programme, whose ambition was to increase the implementation of MAS surgery and offer it to all patients as standard. He urged caution around the potential for industry-sponsored bias, and the individual ethics of people who work in hospitals, which can vary.

3.6.3. A financially constrained NHS

Investments in innovation

The NHS is under increasing financial constraints. The role of the commissioner is changing in response to the evolving financial landscape of the NHS. A finance director (FD1) indicated that, if asked 12 months ago whether commissioners played a role in the business case for service provision, he would have said no. However, increasingly, given the rapid changes in how the NHS is expected to work, discussion around any major reforms would need to include the commissioner. Another financial director (FD2) noted that there were now "11th hour" discussions with commissioners suggesting that they are taking a more active role. In addition, it was explained that a commissioner may provide barriers to investments that lead to changes in service provision, if the procedure attracts a higher tariff but the current (lower-tariff) procedure is considered "acceptable" in terms of service quality (FD2). The investment required to deliver a "Rolls Royce" service may be considered unnecessary, and thereby not supported by the commissioner.

NHS budget constraints have created capital constraints within hospitals, with the result that some hospitals are only able to fund capital projects for backlog projects, not new equipment (DS). In addition, given the financial constraints of the NHS, in some trusts business cases are being forced to adopt a 12 month time frame (i.e. a return on the proposed investment in capital must be seen within one year). (DS). As well as technologies with a high capital outlay, it is important to consider running costs which includes the cost of consumables. Where there is a high cost of disposables, this can be prohibitive; this was noted to be particularly the case in the context of a fixed income (block) contract (DS). One interviewee remarked that "there's no money for anything",

and that if service changes are proposed, they must be cost-neutral or at least in the same ball park, for it to be considered.

It was suggested that efforts to ease the financial barrier to high capital investments could be in the form of negotiations with suppliers, for example through lease agreements where equipment is supplied at running cost during a period of data collection to support the business case, and to train people locally, on site (DS). The same interviewee suggested that it can be helpful to enter into partnerships with suppliers, and gave examples of agreements where the supplier of a piece of capital equipment entered into a 15 year service agreement including investment in buildings (capital estate), capital equipment, managed service agreements, and some staff too (DS).

With regards investments in small capital equipment or disposables to support MAS, it has already been noted that there can be a compromise on quality when cheaper alternatives are adopted (CS2, CS3). This was noted by CS3 to act as a barrier to MAS, where the hospital has opted for lower-quality clinically inferior equipment for financial reasons. Most other interviewees noted that, whilst cost was an important consideration, equipment had to demonstrate at least clinical equivalence in order to be considered, and that quality would not be compromised (CS5, CS8).

Workforce capacity

One surgeon (CS3) noted the decreased utilisation of “waiting list initiatives” (notably the use of weekend lists), which provided flexibility to perform more procedures via MAS, as a barrier to MAS reflecting the financial constraints of the NHS.

As previously discussed one contributor noted that workforce capacity was the factor limiting the ability of the Trust to expand daycase activity.

The director of strategy (DS) noted that “the development of techniques in MAS is outpacing the capacity and training of staff to deliver them”. This was noted to be a function of the national workforce challenge in the clinicians who might to take up those techniques. It was noted that whilst the capital constraint is real, it can be overcome through negotiation. Not having the staff to pick up new techniques is the “single biggest constraint” (DS).

Constrained estate

The impact of a hospital’s infrastructure in relation to MAS was raised by several interviewees. In particular, so called ‘constrained estate’ was described as a motivator for MAS. As described by FD1 who manages a hospital trust with a very constrained estate (low number of beds relative to population served), this constraint was seen as a major motivator for the adoption of MAS, given the associated reduction in length of stay (due to improved recovery times), and the consequently reduced requirement for beds. This was echoed by the other finance director (FD2), explaining that – where there was a trade-off between longer theatre time and reduction in length of stay – there was more weight on the latter. Therefore, the reduced length of stay associated with MAS was seen as a real driver for decision-making at a financial service-planning level. We may speculate that impact on length of stay carries more weight in decision-making where there is an estate constraint.

Several examples were given of the realised impact of the introduction of MAS on the estate requirements of their specialties (CMO, CS2, CS7). For example, one clinician (CS2) noted that the increased use of MAS had reduced the number of beds required for

gynaecology in his hospital from 22 to 8. This was achieved through the reductions in length of stay (from 5.5 days to 95% in less than 1.5 days), that arose from the shift to MAS. Another surgeon (CS7) described the reduction in gynaecology wards (from four to one since 2002) that has been made possible by the reduced LOS on the back of their move to MAS.

3.6.4. Alternative funding sources

Although this was not raised in the literature interviewees highlighted charitable donations as a source of funding for large capital items in the NHS, and therefore a means of purchasing equipment required to improve uptake in MAS. As noted by both finance directors, this can in some cases cause problems for hospitals, where for example there is no associated tariff to achieve reimbursement for the procedure they can now undertake, or high running costs are not able to be covered by the hospital. This can put them in a difficult position with the commissioner (FD1, FD2).

3.6.5. NHS versus private practice

In considering the differences between NHS and private provision of surgical procedures, it is important to note that issues differ by specialty. Notably, surgery for colorectal cancer is performed less often in private practice, given its emergency nature (CS3).

Several clinicians (CS1, CMO, CS3, CS5, CS6, CS8) explicitly stated that the issues facing private and NHS providers were broadly similar, and that clinical considerations were exactly the same (CS2). However, there may be a risk that choice of surgical route is guided more by the skills and preferences of the individual surgeon compared with the NHS; whereas the practice of referring to colleagues is widespread in the NHS, this may be less so in private practice, as clinicians have an interest in suggesting the type of surgery that they can perform (CMO). The increased knowledge and empowerment of the patient can counteract this.

Some surgeons suggested that patient preferences played less of a role in the NHS setting versus the private setting, where patients are more likely to have "done their homework" or "have a fixed idea" of what they would like (CS2, CS3, CM5, CS7). This may relate to the health literacy issue discussed in both the literature review and under the "role of the patient", above. In addition, patient characteristics may be different between the private and public sector, with private sector patients tending to be "healthier", and therefore requiring a shorter hospital stay and so more suitable for MAS (CS3).

It may be that private hospitals have greater financial ability and discretion to invest in the surgical equipment required to deliver MAS. Two surgeons noted that, in a private setting, clinicians have more of a say and more choice regarding the equipment they require, and the hospital is more willing to accommodate individual needs (CS3, CS6), whereas another (CS8) explained that surgeons had more flexibility to access whatever available equipment they wanted, but that investment in new equipment was a more difficult and lengthy process in the private sector, perhaps relating to the lower throughput of patients in private practice which may make the business case for large capital items more difficult (CS2, CS7).

One surgeon (CS3) noted that the pressure arising from emphasis on treatment and waiting list targets, for example, was more acute in the NHS than in private practice, reflecting the financial constraints of the NHS as a major barrier for MAS, which did not translate to the private setting. This means that he is more likely to recommend MAS in

the private setting, where pressures on his time are lower (CS3). This sentiment was contradicted by others, who suggested that the clinical considerations must determine selection of surgical route, and that this does not differ by whether the patient is treated in the private or NHS setting.

3.7. Robotic-assisted MAS

The introduction of robotics was considered by some to be the catalyst to achieving improvements in uptake of MAS, allowing wider utilisation of MAS by more surgeons and for more procedures. This being the case, open surgery may be the more appropriate comparator in an assessment of the clinical- and cost- effectiveness of robotic-assisted MAS. Whilst many professionals believe that the costs of robotics are too high to become part of routine practice across hospitals, others emphasised that robots could promote a quicker learning curve for surgeons, and that costs would reduce over time and as staff became more familiar with the equipment. In the future the patient may have a leading role in demands for service change. The major barrier to the introduction of robotics is cost: recovering the high upfront capital costs of equipment (particularly in low-volume centres). However, even where increasing volume to amortise the capital cost could be addressed, for example by concentrating robotics in a limited number of tertiary referral centres, the high cost of consumables was noted to be particularly prohibitive.

As described in the literature review, the evidence to support the use of robotic-assisted MAS is variable, and differs by procedure. Whilst the evidence suggests that robotic surgery is beneficial in certain procedures, e.g. prostatectomy, and potentially rectal cancer surgery (CS5), evidence of the clinical- and cost-effectiveness of robotics in other specialties is less clear. However, most studies compare the outcomes (and costs) of robotic surgery with regular MAS. As highlighted by the CMO, this may not be the most appropriate comparator. Whilst the clinical- and cost-effectiveness of a procedure should always be judged against the treatment it will be displacing (which is broadly considered to be MAS in most of the specialties we considered in this report), the benefits of robotics are more likely to be seen in expanding the uptake of MAS: in allowing other surgeons, not currently conducting MAS, to conduct MAS with the assistance of a robot. This is because the 3D image provided by a robot is more intuitive than the 2D operation of standard MAS, for which the level of skill required is high, thus making MAS more accessible to more surgeons. If the introduction of robots is the necessary step to convert “the leftovers” to MAS, due, for example, to their more intuitive use and health benefits for the surgeon, then the costs may be outweighed by the clinical benefits (CMO).

Given that the use of robotics is relatively new, it is expected that costs will reduce over time (CS1). As well as the technology becoming more affordable over time, staff will get more efficient at using it (CMO). Indeed, the adoption of robots could support a “quicker” learning curve, particularly in more complex procedures such as colorectal where surgeon skill may be a limiting factor to MAS (CS7).

The patient can have an important role to play in the uptake of robotic surgery, and have already started seeking out and selecting hospitals that provide robotic surgery (CMO). This means that a plausible future is one in which, if hospitals want to deliver the service, they will need to buy one in order to meet this demand (CMO). This was corroborated by another surgeon, who described the business case that was made to purchase a robot within their trust (CS7). A factor that was seen to be critical in the business case was one of status or “kudos”: being at the forefront of technology and

service provision. This was described as having a direct impact on attracting business to the hospital, and responding to the demands of patients who otherwise may go elsewhere to have their surgery undertaken robotically.

The CMO noted that “training comes secondary to critical demand”. For MAS in general, training opportunities have been created in response to demand from the clinical community. Robots represent the next step. For example, urologists have been successful in demonstrating the benefits and leading in the adoption of robotics for prostatectomy; training has been updated in response (CMO).

3.7.1. The ‘next step’ in MAS and service delivery?

It was suggested by one leading surgeon that there was significant room for improvement in the uptake of MAS, and that the adoption of robotic-assisted MAS will be the catalyst to achieve those improvements in uptake (CS1). Wider utilisation of robotic-assisted MAS would allow MAS to be performed with “more confidence”, and could allow a broader range of procedures to be undertaken via minimal access (e.g. head and neck procedures, for which MAS is not generally undertaken because of difficult access issues, and where a robot could facilitate better visibility). In a similar vein, one interviewee noted that the pace of uptake of MAS has slowed down, referencing the fact that the “early wins” had already been made (DS). This supports the notion that the most relevant comparator in terms of impact on outcomes for robotic surgery may be open surgery, rather than MAS. Other interviewees (CS5, CS8) speculated that robotics represent a fashion that was un-substantiated by the evidence-base.

3.7.2. Financial constraints in the NHS and alternative funding sources

The major constraining factor in the adoption of robotic-assisted MAS identified was financial. The feasibility of investment in robotic surgery equipment will be dependent on the volume of cases that can be undertaken in a trust, and thereby the ability to recoup the high upfront capital investment (CS3, FD1). The director of strategy explained that a £1m investment in the context of a £10m capital budget, already in deficit, makes such a commitment impossible at this stage. In low-volume centres such as a district general hospital, patient throughput is likely to be such that the purchase of a robot cannot be justified, given those high upfront costs. There is therefore an argument that robotic technology should be concentrated in a limited number of large tertiary centres (CS3). Indeed, CS6 described the business case put forward for the purchase of a robot in their hospital, which involved combining specialties (colon, urology and gynaecology) and allowing them to take on more complex cases which attracted referrals from elsewhere, thereby increasing volume.

The use of charitable funding is one potential avenue for greater use of robotic MAS, but even covering the initial capital outlay, a barrier for the introduction of robotic MAS is the cost of consumables (CS1). In one example cited, access to a robot is sponsored entirely by a local benefactor, through a charitable donation which covers both the cost of the equipment and the consumable costs (CS5); this has mainly been used by urologists and gynaecologists. Given the difficulty in the financial case for the hospital, this access would not be possible in the absence of the charitable donation.

The finance director of a large hospital (FD1) explained the renting arrangement that the hospital has to utilise a robot from a local private hospital. This was seen as an opportunity to respond to the keen interest among consultants of utilising the technology, without incurring the high capital cost. Uptake has been higher than

expected and it was indicated that they will need to consider the business case for purchasing their own.

For one hospital that had bought a robot outright, the biggest hurdle was described to be dealing with the health authority to secure funding for the costly disposables associated with robotic surgery, which can lead to scenarios where the robot is available, but operational costs limits its use (CS7).

4. OVERCOMING THE BARRIERS

In this section, we provide an overview of the main barriers to uptake of MAS that we have identified through our research, both in the literature and from our interviews with stakeholders. Additionally, and importantly for progress and greater uptake we also provide a commentary on how these barriers could be overcome.

4.1. Silo-thinking in the management of resources

The barrier:

'Invest to save', specifically investing in the theatre time and equipment to deliver MAS is outweighed by the savings accrued from improved recovery and reduced length of stay. However, the costs / benefits may be drawn / accrued from different budgets (operating theatre vs ward). This therefore requires the necessary oversight to balance the costs and savings associated with a move to MAS. Whilst this is generally well understood, this system-wide perspective needs to translate to individual decision-making. There is evidence to suggest that the oversight required to overcome silo budgeting may break down where the pressure of short-term targets and conflicting objectives are the main drivers in day-to-day decision-making. As well as silo-budgets, silo management of staff and facilities can inhibit MAS.

Overcoming the barrier:

Immediate financial pressures should not be permitted to drive short-sighted decision-making. A systems-wide understanding is required to tackle this barrier, in order to understand the trade-offs and allow efficient allocation of resources. This can be supported through various mechanisms. For example:

- The creation and evaluation of *business cases* for investments allows management to adopt the oversight required, across time and budgets. Greater certainty around future reimbursement tariffs for hospitals would support financial planning and business case evaluation. It is important to note that there is generally a value threshold for investments to be considered by management at Trust level. Where smaller capital investments are not considered by such formal means, it is important to make sure decisions are not based solely on cost, at the expense of quality.
- Financial incentives. Specific reimbursement incentives can provide the mechanism for hospitals to support the implementation of best practices. For example, 'best practice tariffs' provide a price 'uplift', designed to help the NHS improve quality by reducing unexplained variation in order to universalise best practice, incentivising high quality and cost-effective care. At the moment, these have only limited applicability to MAS, specifically providing incentives for day-case hernia repair. Applicability to MAS could therefore be expanded to incorporate other relevant procedures. In addition, there is evidence that CQUIN arrangements work, and could be further applied to incentivising MAS.

4.2. The role of surgeon preferences

The barrier:

Surgeon preferences are a product of experience and interpretation of the evidence base, and this varies greatly by clinician. Core medical training plays an important role in preferred techniques, which can be strongly influenced by when the medical professional was trained (with those more recently trained generally being more familiar with and open to MAS) and who they were trained by. The importance of a “clinical champion” to drive change and promote the adoption of technology suggest that, where there isn’t such an individual within an organisation, the necessary enthusiasm to drive change and secure investment in innovation may pose a barrier to MAS.

Overcoming the barrier:

Referral of cases between clinicians should be encouraged and supported (e.g. where MAS would be beneficial but the surgeon is not adequately trained or it is not their preferred technique), and transfer of skills and expertise encouraged. A cultural change required everyone to be on board, across consultants, theatre staff, directors and management. The provision of information to patients and formalising their integration into the decision-making process would provide a catalyst to increase the uptake of MAS.

4.3. Training

The barrier:

Training, and a lack of suitably trained clinical staff, was a key factor identified in both the literature and interviews as a barrier to uptake of MAS. Almost universally it was considered that there was sufficient provision of training courses for MAS, but there was divergence relating to how clinicians can access this training. One of the issues was funding and access to funding, with some clinicians funding their own training. Another factor is the ability for surgeons to practice their skills in settings where patient throughput is insufficient.

Overcoming the barrier:

One solution could be to provide greater funds to support training. In recognition of the importance of training to the improvement of services, such investment in human capital might be more carefully considered at a higher level as an investment opportunity, or incentives provided. The importance of on-the-job training should also be recognised, for which sufficient MAS patient throughput is necessary to allow surgeons to move along the learning curve. Paring (or mentoring) junior staff with more experienced surgeons should be encouraged.

4.4. Financial constraints: capital and workforce

The barrier:

The NHS is under increasing financial pressure to deliver more with less money, and this can impact the uptake of MAS. For example, in some settings day case capacity may be constrained because of workforce shortages; return on investment for capital is required within a limited timeframe due to short term budget constraints; there is reduced flexibility in paying staff overtime to reduce waiting lists, etc. Whilst private practice may not necessarily face exactly the same budget pressures, other constraints are notable e.g. realising return on investments for large ticket items when patient through-put is lower.

Overcoming the barrier:

In order to achieve an efficient allocation of resources, a sufficient time frame should be taken into account to consider all relevant costs and benefits of investments in health; this is distorted where short-term budgetary constraints are allowed to drive decision-making. For projects requiring high capital investments, there can be successful negotiations with suppliers, for example through lease agreements where capital is supplied at running cost while outcomes data are collected. Workforce shortages are a product of a national workforce challenge, which needs to be addressed through incentivising employment and training in those posts. Constrained estate should be regarded as a motivator for MAS, as reduced recovery time in hospital through MAS is a cheap and efficient way to generate extra bed space.

4.5. 'Early wins made'

The barrier:

MAS uptake may have plateaued as the procedures for which MAS has been largely adopted are those most easily transferred to MAS, and the surgeons that have adopted the technique are those most open to it. Therefore, what is left is the more difficult cases and the surgeons who are more resistant to adoption (as characterised by the 's-shaped' curve for uptake of innovation summarised in the introduction).

Overcoming the barrier:

Technological innovation can support an expansion of the application of MAS, either to new procedures or by making MAS amenable to more surgeons. Robotic-assisted MAS represents the innovation that is showing promise to achieve this expansion. However, at the moment the high costs appear to be prohibitive. One solution could be to concentrate the provision of robotic-assisted MAS in large tertiary referral centres. However, this does not address the issue of very costly disposables, for which a more cost-effective solution is required.

5. DISCUSSION

Through a review of the pertinent literature, and analysis of in-depth interviews with a variety of stakeholders, we have set out a number of key barriers that may be inhibiting the uptake of MAS in the UK.

The targeted literature review confirms the relative merits of MAS versus open access surgery. There is evidence of short term clinical benefits of MAS, including lower rates of wound infection, less blood loss, and fewer complications. The evidence is particularly robust with respect to laparoscopic hysterectomy, while there is more heterogeneity in the evidence base for ventral / incisional hernia repair and lower anterior resection. MAS and open have comparable long-term outcomes; the literature finds that recurrence (for cancer or hernia), reoperation rates and overall or disease-free survival are similar in the two types of surgery.

The literature review also identified a number of barriers to the uptake of MAS despite the supportive clinical evidence. These included the accessibility of training, health literacy of patients, the nature of the hospital and the volume of surgery. Using qualitative inquiry we have established the major barriers in a UK context. We asked consultant surgeons, clinicians in leadership roles and finance directors: *why is MAS not utilised more widely in the UK?* We were able to group the findings into five broad (and

sometimes overlapping) themes: clinical and cost effectiveness evidence-base, role of key stakeholders, training, understand the context of service delivery, and future innovations specifically robotics.

There was general support with respect to the clinical evidence-base for MAS. MAS results in short term benefits, including improved recovery and greater patient satisfaction. Although the clinical considerations arguably differ by procedure (and patient). There was recognition of the trade-off between longer operating time and greater costs associated with MAS, and that these could be (in many cases more than) offset by savings from a reduction in hospital length of stay due to improved recovery. A reduction in hospital resources with MAS was deemed to be especially important for hospitals with constrained estate and tight financial resourcing. Budget silos were noted as fostering inefficient decision-making. Improved financial and systems oversight, and reductions in "silo-thinking", are required to enable the right decisions to be made specific to the Trust.

With respect to budgets and planning processes, it was found that investment opportunities relating to MAS are made via the generation of a 'business case', a process driven by clinicians but evaluated by a team with strategic and financial oversight who consider the return on investment. The stakeholders interviewed had different views as to whether this mechanism for financial planning supported investment in equipment to promote MAS. One example given is where some MAS equipment might not be costly enough to be considered formally by management, but may be too expensive to be covered by contingency capital budgets. In this instance, it is important to ensure that decisions are not made on the basis of cost alone, at the expense of quality, thus broader value assessments are required. We found evidence that commissioners were becoming more important stakeholders in the planning process and hence in their ability to influence uptake. The tariff system used in England had the potential to encourage uptake, notably through the use of "best practice" tariffs, which provide a price uplift in order to reduce variation and incentivise best practice. Examples of other commissioning arrangements that could promote MAS were provided, such as Commissioning for Quality and Innovation (CQUIN) payments for reducing rates of open abdominal hysterectomies.

What was evident in the interviews with both consultant surgeons and oversight decision-makers is that individual surgeon preferences play a critical role in the uptake of MAS in any given hospital. The nature of their core medical training, and how long ago this was (with older consultants often more comfortable with open surgery) has a key influence on willingness or ability to conduct MAS. Whilst there has been a drive across the NHS to expand the role of patient choice and to better inform patients, in reality this may still be limited in some settings. The 'Montgomery ruling', passed in 2015, states that informed consent must be collected from patients in advance of a medical procedure. The 'informed' nature of this consent means that patients must be made aware of all of the risks associated with a procedure, and therefore a consideration of the alternative options (Supreme Court, 2015). However, the implementation of this legal obligation by surgeons may be inadequate (Royal College of Surgeons, 2016). Aligned with the important role of the individual surgeon in choice of surgery route is the importance of a "clinical champion" to drive change and fight for investments to support MAS. Beyond procedure-specific considerations, the importance of a 'cultural' change to support MAS was apparent. Arguably this transcends the role of any individual stakeholder, be it the hospital, surgeon or patient.

The literature had identified training as a barrier. In our interviewees, clinicians felt that the opportunities for formal training were numerous. However, various reasons were given as to why these opportunities may not be taken-up, including motivation, the availability of funding (with many surgeons funding their own development in MAS), and lack of time. Stakeholders recognised the importance of ongoing exposure to MAS to maintain and develop the relevant skills was recognised.

Whilst MAS has generally been on an upward trajectory, the pace has slowed or reported by some interviewees to have reversed in some specialties. The financial constraints under which the NHS increasingly operates may be a contributor to this landscape, creating capital constraints for hospitals. Workforce capacity was also noted to be a limiting factor to MAS, with development in MAS techniques outpacing the capacity and training of staff to deliver them. Constrained estate should be seen as a motivator for MAS, which can release bed space by reducing in-hospital recovery time.

Private practice issues were regarded as being broadly similar to those faced by the NHS. Differences identified were the more significant role of patient preferences in the private sector, but a reduced tendency to refer cases to colleagues (thus placing greater emphasis on the skill set of the individual surgeon). Additionally there was agreement from participants that the level of health literacy and baseline health status of private patients may be higher, and clinicians may have greater autonomy to choose their preferred equipment. However, given the smaller throughput of patients in private practice, amortising the cost of large ticket items may make high cost investments problematic.

The introduction of robotics was considered by some to be the catalyst to achieving improvements in uptake of MAS, allowing wider utilisation of MAS by more surgeons and for more procedures. Whilst many professionals believe that the costs of robotics are too high to become part of routine practice across hospitals, others emphasised that robots could promote a quicker learning curve for surgeons, and that costs would reduce over time and as staff became more familiar with the equipment. In the future, the patient may have a leading role in demanding service change. The major barrier to the introduction of robotics is cost: recovering the high upfront capital costs of equipment (particularly in low-volume centres). However, even where increasing volume to amortise the capital cost could be addressed, for example by concentrating robotics in a limited number of tertiary referral centres, the high cost of consumables was noted to be particularly prohibitive. An *affordable* robotic system, which could provide the benefits of MAS, whilst addressing some of the barriers (reducing the burden of training, opening-up MAS to more procedures, and speeding-up the learning curve), could therefore be valuable.

An online survey undertaken by Bryter of 103 gynaecology, colorectal and hernia repair surgeons, sought to understand to what extent some of these issues resonated with a large group of clinicians.¹ Some of the main results are summarised in Box 1 (see Appendix 4 for further details).

The survey results largely support the findings of our research. Whilst MAS can offer savings when taking a whole-systems and longer term view, the immediate direct costs

¹ In order to complement the findings of OHE's report, CMR Surgical commissioned a survey to canvas the opinions of a large sample of consultant surgeons. The design of the survey and questions were influenced by early insights from OHE Consulting's interview analysis. The survey was conducted and data analysed by Bryter, a market research agency. Further details of the survey are attached, in Appendix 4.

of MAS are still considered an important barrier; this is also reflected in the fact that nearly half the respondents believed budget silos hinders the adoption of MAS. Indirect and longer term cost savings, across NHS departments, must be taken into consideration. The main barrier to the provision of MAS was identified to be an insufficient number of trained surgeons, and inadequate referral to clinicians with the right skills was confirmed. There is also a need to promote an enabling environment for surgical innovation in the NHS; only 30% of surgeons surveyed believed that support and incentives to evaluate and adopt surgical innovation were adequate. Financial constraints on the NHS and high upfront costs of robotics were confirmed to be the major barrier to their adoption.

Box 1. Results of a market research survey

What do surgeons think?

103 UK surgeons who conduct gynaecological, colorectal and/or hernia repair procedures were asked their opinions on barriers to MAS in a market research survey by Bryter. Some of the important findings:

SUPPORTING INNOVATION

- Only 30% believed there is support and incentives in the NHS for surgical innovation.
- A surgeon-led approach (74%) and desire to provide the best care for patients (71%) are thought the most important factors to successful adoption of innovative surgical technology.

ROBOTICS

- 96% indicated that upfront costs are a barrier to the adoption of robotics.
- Financial constraints was the most widely identified barrier (83%) to RAS (robot-assisted surgery) being offered to appropriate patients.

TRAINING AND REFERRAL

- Insufficient number of surgeons being trained in MAS techniques was identified as the main limitation to the provision of MAS within the NHS (81% of surgeons undertaking gynaecological procedures, 45% of colorectal surgeons and 40% of hernia repair surgeons).
- The third most important barrier identified was insufficient referral between clinicians (44% of gynaecologists, 26% of colorectal surgeons and 28% of hernia repair surgeons).

MAS COSTS AND SAVINGS

- 59% believed indirect cost reduction (e.g. reduced length of stay) was an important factor for the successful adoption of innovative surgical technology.
- Nearly half of surgeons (46%) agreed the adoption of MAS reduces financial burden on the NHS.
- Financial constraints due to the direct cost of MAS was rated as the second most important barrier, with 56% of hernia repair surgeons selecting this option (along with 28% of gynaecologists and 24% of colorectal surgeons).

BUDGET SILOS

- Nearly half (49%) of surgeons felt that the financial structure of NHS trusts hinders the adoption of MAS.

Source: Bryter. See Appendix 4 for further details

It is noteworthy that the findings of our research resonate with those from nearly a decade earlier from the Royal College of Surgeons (RCS). The RCS convened a group of experts to consider the challenges and barriers to translational research in surgery (Royal College of Surgeons, 2011). They made a number of recommendations which align with our results.

Three key influences on the uptake of innovation identified were:

- The availability of national guidance of appropriate use, and in particular the fact that many surgical interventions are not subject to technology appraisal guidance by the NICE.
- The establishment of training programmes to ensure surgeons are not just capable but also proficient in new techniques.
- The availability of information on surgical trials and studies, to allow surgeons to participate or refer patients and monitor technology development in order to gain familiarity.

They also identified levers to encourage uptake including:

- Creating choice guarantees so patients are not disadvantaged where a surgeon chooses not to adopt a new technique despite evidence of benefit to the patient.
- Publishing information on uptake, so that it can be a point of differentiation.
- Providing information to patients to allow them to make an informed decision.
- Disseminating information to clinicians so they are aware of new practices.
- Incentivising uptake of new technologies via the Commissioning for Quality Innovation (CQUIN) schemes.
- Creating best practice tariffs to incentivise the use of clinically superior interventions.
- Including innovation assessment in the surgeons' revalidation process.

One of the main concerns highlighted in the RCS report was the forthcoming changes to training budgets as proposed in a NHS White Paper (Department of Health, 2010). There was concern that devolving them to individual providers was not as efficient as regional national surgical training programmes. They recommended that there should be training incentives in tariffs encourage the use of new techniques and incentivise continuing professional development.

Our study with a specific focus on MAS and a forward view to robotics (rather than their broad focus on translational research), identified similar issues despite a number of the recommendations that were made by the RCS being implemented (e.g. best practice tariffs and CQUIN schemes). This suggests there is clearly still a need to change the system in order to promote the uptake of innovation. It would seem that MAS as an innovation in surgery is not alone in the barriers it faces.

Indeed these barriers are wider than surgical innovations. The recent Accelerated Access Review (AAR) makes a number of recommendations to improve patients' access to innovative technologies, including medicines, medical technologies, diagnostics and digital products (Taylor, 2016). The Government, in commissioning this independent inquiry, recognised the fundamental role innovation plays in improving patient care and patient outcomes. The AAR together with the Life Sciences Industrial Strategy (Bell, 2017) reflects a changing paradigm in the UK, and hopefully the catalyst for greater adoption of surgical innovations, including MAS.

5.1. Limitations

Despite our findings resonating with earlier research it is important to highlight the limitations in our approach. In particular, response bias is likely to have affected the nature of our sample and the perspectives we were exposed to; those willing to participate in the research, and to give up an hour of their time, are more likely to be those motivated to understand or indeed overcome the barriers to MAS. Indeed,

although the Trusts for whom our interviewees worked represented a range of high/low adopters, the surgeons themselves that we spoke to were mainly supportive of MAS. Given the desire to understand the barriers, this is a natural limitation of our research. In addition, we were unable to secure an interview with someone that has financial oversight of a private health care provider, although most of the surgeons were active in private practice alongside NHS.

It is also important to note that our qualitative approach does not provide (and does not, by design, intend to provide) a “consensus”. Given the hugely complicated and multi-faceted nature of implementation issues in the NHS, it would be implausible to assert that in 12 interviews we have been able to capture every issue and perspective. However, by building up our framework and analysing and organising our data within those themes, interview by interview, we are able to have confidence that no new ‘themes’ were arising from additional interviews towards the end of our sample. Therefore, we felt that the benefit of increasing our sample size would be modest.

6. CONCLUSION

The evidence base to support MAS is generally well established, and supported through NICE guidance. The benefits of MAS can include shorter recovery time, reduced length of stay in hospital and therefore cost savings to the NHS. Nevertheless, uptake is variable. In this report we have identified in both the literature and through interviews with key stakeholders a number of barriers to the greater uptake of MAS, and potential solutions to overcoming these barriers.

It is important to acknowledge that this report has been written at a time when the NHS has never been more financially constrained. However, the investment in MAS (via capital and training) can improve service delivery and importantly reduce recovery time. Therefore, there are clear returns on the investment: where used appropriately, MAS can improve patient outcomes whilst promoting the efficient use of NHS resources. However, a whole-systems view needs to be adopted, and the health system – through use of appropriate incentives and workforce planning – must create a supportive environment for the implementation of best practices. Adoption decisions require implementation; the clinical workforce needs to be convinced of the benefits, and improved access to training is required. A prime catalyst would be a cultural change affecting all stakeholders. Increasingly, a more informed patient population is taking this role.

The forthcoming robotic era means MAS is at a crossroads. What is important now is that surgical innovators and the health care system seize the opportunities created by both the financial climate and the changing paradigm, to realise the opportunity to improve patient outcomes and address the variation that currently exists for MAS in the UK.

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APPENDIX

Appendix 1 – Literature search strategy

Table A1: PubMed search terms

Search number	Search term
1	(((((minimal[All Fields] AND access[All Fields]) OR (minimally[All Fields] AND invasive[All Fields]))) OR ("laparoscopy"[MeSH Terms] OR "laparoscopy"[All Fields] OR "laparoscopic"[All Fields])) OR ("laparoscopy"[MeSH Terms] OR "laparoscopy"[All Fields])) AND open[All Fields]) OR ("laparotomy"[MeSH Terms] OR "laparotomy"[All Fields]))
2	(Economics[MeSH Terms])
3	((hernia) AND (ventral OR incisional))
4	("hysterectomy"[MeSH Terms] OR "hysterectomy"[All Fields])
5	(((((anterior resection) AND (rectum OR rectal OR colon OR intestin*)))) OR ("lower anterior resection") OR "low anterior resection")) OR total mesorectal excision)
6	1 AND 3
7	1 AND 4
8	1 AND 5
9	2 AND 6
10	2 AND 7
11	2 AND 8

The clinical impact of minimal-access versus open-access surgery employed searches 6 to 8 to identify relevant literature in PubMed. The economic impact of minimal-access versus open-access surgery used searches 9 to 11, with supplementary literature searches conducted using the Cochrane Library, Google Scholar, and NHS Economic Evaluation Database (NHS EED). Studies were excluded on the basis of relevance, for example not being a comparison of MAS and open access, inadequate study methodology, analysis of specific outcome which is out of scope, incorrect procedure etc.

Appendix 2 – Semi-structured interview guide

Barriers to the adoption of minimal access surgery

1. How do you feel the level of MAS undertaken in your hospital / trust compares with others?
2. Do you have an overall perspective on the benefits or use of minimal-access surgery (MAS), compared with open-access surgery, in your hospital/trust?
3. From your perspective, how has the utilisation of MAS changed over time?
4. Are you aware of the clinical effectiveness of MAS versus open-access?
 - a. Does this differ according to the procedure?
5. Are there any perceived or experienced complications, safety concerns or contraindications that have influenced the utilisation of MAS in your hospital?
6. To what extent do individual patient characteristics determine the decision on mode of access for surgery? Does patient choice play a role?
7. What is the role of the individual clinician in influencing the surgical approach adopted? Does clinician preference or background have a strong influence on the adoption of MAS?
8. Is training or support provided? Is this offered on a regular basis?
9. Are you aware of the *cost* effectiveness of MAS versus open-access?
 - a. Does this differ according to the procedure?
10. What are your views on the budget implications of MAS relative to open-access surgery? Do these present a barrier or an incentive for the adoption of MAS?
11. In general, MAS is associated with longer surgical operating times, but a shorter length of hospital stay and lower longer term costs. To what extent is there a trade-off between short-term and long-term costs/savings, and does one play a greater role in decision-making than the other? Are costs/savings realised from the same or different budgets?
12. To what extent does upfront investment in capital act as a barrier to the adoption of MAS? Has this changed over time?
13. Do you have a view on or experience of the uptake of MAS in the NHS versus the private sector, and any differences in decision-making?
14. What is the process by which surgical innovations are adopted in your trust?

Appendix 3 – Themes identified in the qualitative analysis

Table A2: Qualitative analysis themes

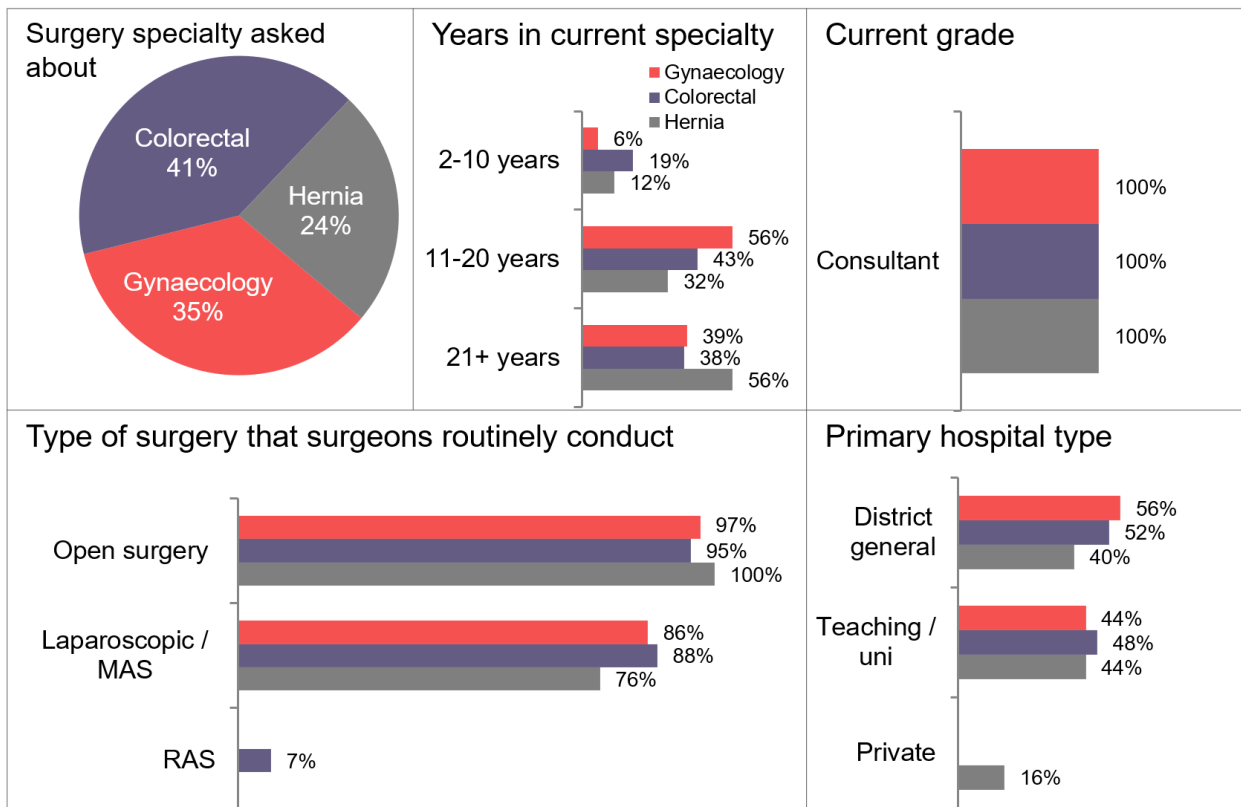
Theme	Sub-theme	Further coding
Clinical- and cost effectiveness of MAS	Clinical effectiveness	<ul style="list-style-type: none"> • Outcomes • Safety • Contraindications • Belief in the evidence-base
	Cost effectiveness	<ul style="list-style-type: none"> • Trade-off between short-term costs and longer-term gains? • “Silo thinking”
Role of the key stakeholders in MAS	Role of the hospital and commissioner	<ul style="list-style-type: none"> • Considering investment opportunities: evaluating the “business case” • Reimbursement of MAS
	Role of the surgeon	<ul style="list-style-type: none"> • Surgeon preferences and characteristics • Importance of a clinical champion • Referring cases to colleagues
	Role of the patient A “cultural” change	
Training	Availability of training opportunities	
	Uptake of training	
	Patient throughput and the learning curve	
Context for service delivery	Awareness of level of adoption	
	Trends in MAS over time	<ul style="list-style-type: none"> • Initiatives to reduce waiting lists • UK versus international uptake • ‘Drive’
	A financially constrained NHS	<ul style="list-style-type: none"> • Investments in innovation • Workforce capacity • Constrained estate
	Alternative funding sources NHS versus private practice	
Robotic-assisted MAS	‘Next step’ in MAS and service delivery	
	Financial constraints in the NHS and alternative funding sources	

Appendix 4 – Bryter Survey of Surgeons

Survey methodology

Bryter surveyed a sample of 103 surgeons in the UK, performing gynaecological, colorectal, and/or hernia repair operations, in February 2018. The survey was conducted online. The design of the survey and questions were influenced by early insights from OHE Consulting’s interview analysis. The survey was funded by CMR Surgical.

Surgeon profile



Results

What percentage of your (GYNAECOLOGICAL / COLORECTAL / HERNIA REPAIR) procedures are conducted using minimal access surgery (MAS)?				
	Specialty			
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
None	10	2	2	6
	9.71%	5.56%	4.76%	24.00%
1-25%	22	8	7	7
	21.36%	22.22%	16.67%	28.00%
26-50%	21	7	7	7
	20.39%	19.44%	16.67%	28.00%
51-75%	26	10	13	3
	25.24%	27.78%	30.95%	12.00%
76-100%	23	8	13	2
	22.33%	22.22%	30.95%	8.00%
Don't know	1	1	0	0
	0.97%	2.78%	0.00%	0.00%

Based on your clinical experience and the reported clinical evidence, which of the following best describes your opinion of the outcomes provided by minimal access surgery (MAS) compared to open surgery for (GYNAECOLOGICAL / COLORECTAL / HERNIA REPAIR) procedures?				
	Specialty			
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
MAS leads to INFERIOR outcomes compared to open surgery	4	0	1	3
	3.88%	0.00%	2.38%	12.00%
MAS leads to EQUIVALENT outcomes compared to open surgery	43	14	14	15
	41.75%	38.89%	33.33%	60.00%
MAS leads to SUPERIOR outcomes compared to open surgery	54	21	26	7
	52.43%	58.33%	61.90%	28.00%
None of the above / don't know	2	1	1	0
	1.94%	2.78%	2.38%	0.00%

What do you think are the main limitations to providing MAS procedures to patients requiring (GYNAECOLOGICAL / COLORECTAL / HERNIA REPAIR) surgery on the NHS?				
		Specialty		
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
Financial constraints due to the direct costs of MAS	34	10	10	14
	33.01%	27.78%	23.81%	56.00%
Insufficient surgeons trained in MAS techniques	58	29	19	10
	56.31%	80.56%	45.24%	40.00%
Insufficient throughput of patients for surgeons to become proficient in MAS	15	7	3	5
	14.56%	19.44%	7.14%	20.00%
Patient preference	5	2	2	1
	4.85%	5.56%	4.76%	4.00%
Physical challenges on the surgeon (e.g. fatigue and injury)	14	5	7	2
	13.59%	13.89%	16.67%	8.00%
Insufficient referral between clinicians (e.g. open surgeons being reluctant to refer to colleagues with more experience of MAS)	34	16	11	7
	33.01%	44.44%	26.19%	28.00%
Inadequate evidence to support the value of MAS	11	1	4	6
	10.68%	2.78%	9.52%	24.00%
Don't know	12	1	9	2
	11.65%	2.78%	21.43%	8.00%

To what extent do you agree, or disagree with each of the following statements?		
	“Greater adoption of MAS is one way of reducing financial pressure on the NHS”	“There are enough support and incentives in the NHS to evaluate and adopt new surgical innovation”
Base	103	103
Strongly disagree (1.0)	6	10
	5.83%	9.71%
Tend to disagree (2.0)	23	41
	22.33%	39.81%
Neither agree nor disagree (3.0)	24	20
	23.30%	19.42%
Tend to agree (4.0)	24	26
	23.30%	25.24%
Strongly agree (5.0)	23	5
	22.33%	4.85%
Don't know	3	1
	2.91%	0.97%
NET: Disagree	29	51
	28.16%	49.51%
NET: Agree	47	31
	45.63%	30.10%

Do you think the financial structure of NHS trusts (i.e. siloed budgets) hinders the adoption of MAS?				
		Specialty		
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
Yes	50	18	19	13
	48.54%	50.00%	45.24%	52.00%
No	34	11	15	8
	33.01%	30.56%	35.71%	32.00%
Don't know	19	7	8	4
	18.45%	19.44%	19.05%	16.00%

What do you consider to be the top three key drivers to successful adoption of innovative surgical technology?				
		Specialty		
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
Surgeon led	76	25	32	19
	73.79%	69.44%	76.19%	76.00%
Chief Executive led	11	1	6	4
	10.68%	2.78%	14.29%	16.00%
Patient led	29	7	19	3
	28.16%	19.44%	45.24%	12.00%
Direct cost reduction	42	13	17	12
	40.78%	36.11%	40.48%	48.00%
Indirect cost reduction (e.g. reduced length of stay)	61	23	23	15
	59.22%	63.89%	54.76%	60.00%
Delivering the best care for patients based on evidence	73	29	26	18
	70.87%	80.56%	61.90%	72.00%
Don't know	1	1	0	0
	0.97%	2.78%	0.00%	0.00%

We would now like to ask you about Robotic Assisted Surgery - Do you think upfront capital costs are a barrier to the adoption of robotics?				
		Specialty		
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
Yes	99	35	41	23
	96.12%	97.22%	97.62%	92.00%
No	2	0	1	1
	1.94%	0.00%	2.38%	4.00%
Don't know	2	1	0	1
	1.94%	2.78%	0.00%	4.00%

What do you think are the top three barriers to robotics being offered to all patients for whom it would be appropriate?				
		Specialty		
	Total	Gynaecological	Colorectal	Hernia repair
Base	103	36	42	25
Financial constraints due to the direct costs of MAS	85	29	35	21
	82.52%	80.56%	83.33%	84.00%
Insufficient surgeons trained in MAS techniques	59	21	23	15
	57.28%	58.33%	54.76%	60.00%
Insufficient throughput of patients for surgeons to become proficient in robotic-assisted MAS	38	16	13	9
	36.89%	44.44%	30.95%	36.00%
Patient preference	3	0	2	1
	2.91%	0.00%	4.76%	4.00%
Physical challenges on the surgeon (e.g. fatigue and injury)	3	2	0	1
	2.91%	5.56%	0.00%	4.00%
Insufficient referral between clinicians (e.g. open surgeons being reluctant to refer to colleagues with more experience of robotic-assisted MAS)	19	6	8	5
	18.45%	16.67%	19.05%	20.00%
Inadequate evidence to support the value of robotic-assisted MAS	75	25	32	18
	72.82%	69.44%	76.19%	72.00%
Don't know	3	1	2	0
	2.91%	2.78%	4.76%	0.00%