Minimally invasive surgery: early concepts to gold standards

Traditionally, surgery of the abdomen and pelvis has been through the open approach. However, with technological advances, surgical specialities have embraced the benefits of minimally invasive surgery, both for the surgeon and the patient.

History of minimally invasive surgery

The first successful elective laparotomy was performed in 1809 by Ephraim McDowell to resect a 10.2 kg ovarian tumour (Ellis, 2015). Since then, open surgery, or a laparotomy of the abdomen, has remained the gold standard for many procedures.

The early concepts of minimally invasive surgery originate as far back as Hippocrates who, in 400BC, detailed the use of a speculum to examine haemorrhoids. The 19th century saw further developments of a light source, with Bozzini's Lichtleiter (1806), Segalas' urethro-cystique (1826) and Nitze's kystoskop (1877) (St. Peter and Holcomb, 2008).

Bernheim reported the first laparoscopy in 1911, and since then there have been a myriad of developments in technology and technique: CO_2 insufflation (1910), Veress' spring-loaded needle for induction of a pneumoperitoneum (1938), Kalk's 135° lens (1929), Hopkins' fibreoptic prototype (1954) and the Hasson technique for direct visualisation of port placement (1974) (St. Peter and Holcomb, 2008). These advances meant that minimally invasive surgery could be more widely adopted, to offer patient benefits compared to a laparotomy.

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Current status

There are many procedures where the minimally invasive approach has either become the new gold standard or is being used more frequently because of the associated benefits for the patient.

Cholecystectomy is a very common procedure, and the open approach has been the gold standard for over 100 years, with the laparoscopic alternative introduced in the 1980s (Keus et al, 2006). The National Institute of Health Consensus Development Conference found laparoscopic cholecystectomy to be preferential to the open technique (Gollan et al, 1993), and this is now the gold standard (National Institute for Health and Care Excellence, 2014). A Cochrane systematic review (Keus et al, 2006), comparing laparoscopic and open cholecystectomy for patients with symptomatic cholecystolithiasis, found no significant differences in mortality, complications and operative time between the two techniques, but found that the laparoscopic technique was associated with significantly shorter hospital stay and quicker convalescence.

Open partial nephrectomy remains the gold standard in the treatment of small renal masses. Despite this, at the Royal Free Hospital, only 8% of all renal operations are via the open approach, with 12% performed laparoscopically and 80% robotically. This is because of the many associated patient benefits of minimally invasive surgery.

Laparoscopic partial nephrectomy is as effective as open partial nephrectomy (Benidir et al, 2014), offering comparable long-term oncological and functional outcomes (Cha et al, 2011). Laparoscopic partial nephrectomy is associated with postoperative benefits for the patient (decreased blood loss, shorter length of stay, improved cosmesis and shorter convalescence) (Cha et al, 2011), but it should only be performed by a surgeon experienced in the laparoscopic procedure.

Robotic-assisted partial nephrectomy was first described by Gettman et al in 2004. Like laparoscopic partial nephrectomy, its minimally invasive approach has many patient benefits. A comparative study found that robotic-assisted partial nephrectomy had shorter warm ischaemia time than laparoscopic partial nephrectomy (although open partial nephrectomy had the shortest), the lowest estimated blood loss, and lower morbidity (intra- and postoperative complications) and lower rates of positive surgical margins than open partial nephrectomy (Porpiglia et al, 2016).

Laparoscopic appendectomy uses a significantly smaller incision than the open approach (Ruffolo et al, 2013). A Cochrane review (Sauerland et al, 2010) showed this minimal invasiveness was associated with reduced postoperative pain, reduced wound infection rate and shorter convalescence, as well as better cosmesis. Minimally invasive surgery offers clear advantages and should be preferred in obese patients, older patients and patients with comorbidities (Di Saverio et al, 2016). These patients would be poorer candidates for maximally invasive (open) surgery, because they have a reduced physiological reserve to recover from surgery.

Open radical prostatectomy was the traditional approach, but robotic-assisted radical prostatectomy has now become the gold standard in the treatment of localized prostate cancer (Mottet et al, 2015). A Cochrane review (Ilic et al, 2017) found that laparoscopic radical prostatectomy and robotic-assisted radical prostatectomy were similar to the open approach in terms of urinary and sexual quality of life-related outcomes, and that differences in postoperative pain were minimal, but the minimally invasive approach had shorter length of stay and less blood loss compared to open radical prostatectomy.

When comparing a laparotomy to minimally invasive surgery, a large incision in the abdominal wall is replaced by several smaller incisions, which offers the patient better cosmesis. There have been developments towards single port surgery (single incision laparoscopic surgery and the Da Vinci SP (Intuitive Surgical, Inc, Sunnyvale, Calif) or even hidden incisions (natural orifice transluminal endoscopic surgery).

Benefits to the patient

The many patient benefits associated with this type of surgery are a result of the minimally invasive nature of the procedure. Smaller wounds allow quicker recovery and convalescence, as shown by the Cochrane review for cholecystectomy (Keus et al, 2006). Robotic-assisted partial nephrectomy offers superior oncological outcomes to open partial nephrectomy, and decreased warm ischaemia time allows preservation of functional renal parenchyma, improving the patient's functional outcomes, alongside the associated decrease in total morbidity.

Laparoscopic approach to appendectomy is associated with reduced postoperative pain, reduced wound infection rate and a shorter convalescence, and is even preferred for patients who are poorer candidates for open surgery. With regards to radical prostatectomies, while achieving similar results to the open approach in terms of urinary and sexual quality of life-related outcomes, the patient benefits from shorter length of stay and blood loss.

Limitations of minimally invasive surgery

There are contraindications to the use of minimally invasive surgery. Patients with physiological limitations are poor candidates for minimally invasive surgery (Bowers and Hunter, 2006). Patients with severe hypovolaemia may not compensate well and may experience a large fall in cardiac output following insufflation. The Trendelenburg position and insufflation can also increase intracranial pressure, and is therefore contraindicated in patients with an already elevated intracranial pressure, and those with glaucoma.

The patient benefits of minimally invasive surgery can be lost when there are laparoscopic entry access injuries. A study looking at claims arising from American and non-American entry access injuries (Chandler et al, 2001) found that the most commonly reported injuries were to the small bowel and iliac artery. With any form of internal injury, such as uncontrolled bleeding, and limited accessibility, there will be times when there is a need to convert to a laparotomy. At this point, the patient loses all associated benefits of minimally invasive surgery. So, while minimally invasive surgery offers many potential benefits, it is important for the surgeon to consult the patient about the associated risks as well, and the potential need to convert to an open procedure.

As minimally invasive surgery is relatively new for many procedures, long-term follow up is required to effectively prove that the new minimally invasive approaches offer superior oncological outcomes (in the case of cancer) to the current gold standard. Most minimally invasive surgery procedures have already been shown to be safe and feasible and, even in early findings, offer superior functional outcomes to a laparotomy.

Conclusions

The benefit of performing minimally invasive surgery over a laparotomy is that often, comparable oncological and superior functional outcomes are achieved, which means that the patient is able to gain more from the procedure. Even so, patient selection remains important to ensure maximum benefit from the procedure. Just because minimally invasive surgery can be performed does not mean that it should be performed on all patients, as outlined by the limitations in certain patient groups and the associated risk of complications. For many patients, minimally invasive surgery is beneficial compared to laparotomy, especially with regards to superior postoperative functional outcomes. **BJHM**

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KEY POINTS

- There are many procedures where minimally invasive surgery is recognized as the gold standard, and in others it is being used more frequently because of the associated benefits for the patient.
- Minimally invasive surgery should be preferred in obese patients, older patients and patients with comorbidities that make them poor candidates for open surgery.
- Patient benefits of minimally invasive surgery include quicker recovery, smaller wounds, improved cosmesis, shorter length of stay and reduced blood loss.
- Patient selection is important. Just because minimally invasive surgery can be performed does not mean that all patients are suitable for it.

Benidir T, Coelho de Castilho TJ, Cherubini GR, de Almeida Luz M. Laparoscopic partial nephrectomy for renal cell carcinoma in a horseshoe kidney. Can Urol Assoc J. 2014 Nov;8(11-12):E918–E920. https://doi.org/10.5489/cuaj.2289

Bowers SP, Hunter JG. 2006. Contraindications to Laparoscopy. In: Whelan RL, Fleshman JW, Fowler DL, eds. The SAGES Manual of Perioperative Care in Minimally Invasive Surgery. New York: Springer-Verlag: 25–32

Cha EK, Lee DJ, Del Pizzo JJ. Current status of robotic partial nephrectomy (RPN). BJU Int. 2011 Sep;108(6 Pt 2):935–941. https://doi.org/10.1111/j.1464-410X.2011.10556.x

Chandler JG, Corson SL, Way LW. Three spectra of laparoscopic entry access injuries. J Am Coll Surg. 2001 Apr;192(4):478-90; discussion 490-1. https://doi.org/10.1016/S1072-7515(01)00820-1

Di Saverio S, Birindelli A, Kelly MD et al. WSES Jerusalem guidelines for diagnosis and treatment of acute appendicitis. World J Emerg Surg. 2016 Dec;11(1):34. https://doi.org/10.1186/s13017-016-0090-5

Ellis H. The first successful elective laparotomy. J Perioper Pract. 2015 Oct;25(10):207–208. https://doi.org/10.1177/175045891502501005

Gettman MT, Blute ML, Chow GK, Neururer R, Bartsch G, Peschel R. Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with da Vinci robotic system. Urology. 2004 Nov;64(5):914–918. https://doi.org/10.1016/j.urology.2004.06.049

Gollan JL, Bulkley GB, Diehl AM et al. National Institutes of Health Consensus Development Conference Statement: Gallstones and Laparoscopic Cholecystectomy. September 14-16, 1992. J Laparoendosc Surg. 1993;3(1):77–90. https://doi.org/10.1089/lps.1993.3.77

Ilic D, Evans SM, Allan CA, Jung JH, Murphy D, Frydenberg M. Laparoscopic and robotic-assisted versus open radical prostatectomy for the treatment of localised prostate cancer. Cochrane Database Syst Rev. 2017 Sep 12;9:CD009625. https://doi.org/10.1002/14651858.CD009625.pub2

Keus F, de Jong J, Gooszen HG, Laarhoven CJ. Laparoscopic versus open cholecystectomy for patients with symptomatic cholecystolithiasis. Cochrane Database Syst Rev. 2006 Oct 18;(4):CD006231. https://doi.org/10.1002/14651858.CD006231

Mottet N, Bellmunt J, Briers E et al. 2015. Guidelines on prostate cancer. (accessed 6 February 2019) https://uroweb.org/wp-content/uploads/EAU-Guidelines-Prostate-Cancer-2015-v2.pdf

National Institute for Health and Care Excellence. 2014. Gallstone disease: diagnosis and management. (accessed 30 January 2019) https://www.nice.org.uk/guidance/cg188/chapter/1-recommendations

Porpiglia F, Mari A, Bertolo R et al. Partial nephrectomy in clinical T1b renal tumors: multicenter comparative study of open, laparoscopic and robot-assisted approach (the RECORd Project). Urology. 2016 Mar;89:45–51. https://doi.org/10.1016/j.urology.2015.08.049

Ruffolo C, Fiorot A, Pagura G et al. Acute appendicitis: what is the gold standard of treatment? World J Gastroenterol. 2013;19(47):8799–8807. https://doi.org/10.3748/wjg.v19.i47.8799

Sauerland S, Jaschinski T, Neugebauer EA. Laparoscopic versus open surgery for suspected appendicitis. Cochrane Database Syst Rev. 2010 Oct 6;(10):CD001546. https://doi.org/0.1002/14651858.CD001546.pub3

St. Peter SD, Holcomb GW. 2008. History of Minimally Invasive Surgery. Philadelphia: Elsevier Inc.