International Journal of Surgery 10 (2012) 345–354

Contents lists available at SciVerse ScienceDirect

International Journal of Surgery

journal homepage: www.theijs.com

Review

A technical review of flexible endoscopic multitasking platforms

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ARTICLE INFO

Article history:
Received 31 January 2012
Received in revised form
4 April 2012
Accepted 19 May 2012
Available online 26 May 2012

Keywords:
NOTES
Flexible endoscopic multitasking platform
Endoscopic
Robotic
Surgery

ABSTRACT

Background: Further development of advanced therapeutic endoscopic techniques and natural orifice translumenal endoscopic surgery (NOTES) requires a powerful flexible endoscopic multitasking platform.
Methods: Medline search was performed to identify literature relating to flexible endoscopic multitasking platform from year 2004–2011 using keywords: Flexible endoscopic multitasking platform, NOTES, Instrumentation, Endoscopic robotic surgery, and specific names of various endoscopic multitasking platforms. Key articles from articles references were reviewed.
Results: Flexible multitasking platforms can be classified as either mechanical or robotic. Purely mechanical systems include the dual channel endoscope (DCE) (Olympus), R-Scope (Olympus), the EndoSamurai (Olympus), the ANUBIScope (Karl-Storz), Incisionless Operating Platform (IOP) (USGI), and DDES system (Boston Scientific). Robotic systems include the MASTER system (Nanyang University, Singapore) and the Viacath (Hansen Medical). The DCE, the R-Scope, the EndoSamurai and the ANUBIScope have integrated visual function and instrument manipulation function. The IOP and DDES systems rely on the conventional flexible endoscope for visualization, and instrument manipulation is integrated through the use of a flexible, often lockable, multichannel access device. The advantage of the access device concept is that it allows optics and instrument dissociation. Due to the anatomical constrains of the pharynx, systems are designed to have a diameter of less than 20 mm. All systems are controlled by traction cable system actuated either by hand or by robotic machinery. In a flexible system, this method of actuation inevitably leads to significant hysteresis. This problem will be accentuated with a long endoscope such as that required in performing colonic procedures. Systems often require multiple operators. To date, the DCE, the R-Scope, the IOP, and the Viacath system have data published relating to their application in human.
Conclusion: Alternative forms of instrument actuation, camera control and master console ergonomics should be explored to improve instrument precision, sphere of action, size and minimize assistance required.

1. Introduction

Since the introduction of the concept of Natural Orifice Translumenal Endoscopic Surgery (NOTES) when Kalloo et al in 2004 published their experience of transgastric peritoneoscopy in a porcine model, the benefits of NOTES has been disputed.[1] The purported benefit of NOTES is that it reduces parietal injury thus minimizes pain, scar and acute injury response associated with surgery. Various routes have been experimented; transgastric and transvaginal routes are the two most popular access routes for intra-abdominal surgery.[2] Currently there is a lack of evidence that performing intraperitoneal surgery via NOTES technique is superior to conventional open or laparoscopic techniques. A review of 432 human NOTES cases demonstrated that the majority of procedures involved combination of conventional laparoscopy and translumenal endoscopic therapy.[3] This may be associated with increased number of operators required per procedure. Operative times presented in an international prospective case series which assessed a total of 362 transvaginal and transgastric NOTES procedures, appeared to be longer than what would be expected when compared to conventional laparoscopic procedures. Additional complications that would not be encountered in standard laparoscopic or open techniques were noted, these include vaginal laceration, oesophageal injury and mediastinitis.[4] In a German case series consisted of 551 patients who underwent transvaginal NOTES procedure, of which 85.3% were cholecystectomy; it reported

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doi:10.1016/j.ijsu.2012.05.009

four cases of bladder injuries, two cases of rectal injury, two cases of vaginal bleed, and three cases of vaginal infection.[5]

Although the benefit of NOTES in performing intraperitoneal surgery remains unproven, the benefit of advanced endolumenal therapy is tantalizing. These techniques target conditions treatable within the lumen without iatrogenic breech of viscus wall. Endoscopic submucosal dissection (ESD) for early gastrointestinal cancer and peroral endoscopic myotomy (POEM) for oesophageal achalasia are examples of these techniques.

Endoscopic submucosal dissection is a technique developed with the aim of removing lesions en bloc that would otherwise be impossible with endoscopic mucosal resection (EMR).[6] The Japanese Gastric Cancer Association recommends that moderately or well differentiated gastric cancer that is not associated with an ulcer; limited to the mucosal layer; and of lesser than 2 cm in diameter in elevated type lesion and lesser than 1 cm in diameter in depressed type lesion, is suitable for endoscopic excision.[7,8] EMR is proven to be an effective treatment for early gastric cancer.[9] With histological evidence that even larger mucosal tumours,[10] as well as undifferentiated tumours involving only the upper third of the submucosal layer (Sm1) can be without lymph node involvement,[11] some have suggested that tumour lesser than 3 cm with minimal submucosal involvement can be treated endoscopically.[10] EMR for these expanded criteria lesions may be associated with risk of incomplete excision. ESD is associated with improved en bloc resection rate and thus allow better assessment of resection margin.[12] Case studies suggest that ESD is associated with superior complete resection rate for larger lesions and has a lower risk of local recurrence.[13,14] There remains a need for prospective randomized controlled trial comparing endoscopic treatment of gastric cancer versus conventional surgery. More recently, ESD has also been applied to oesophageal cancer. Early reports are promising.[15]

With the success of endoscopic treatment of early gastric cancer, EMR and ESD have been used to treat large sessile colonic polyps and early colonic tumours. The indication is much less defined than for gastric cancer. ESD is distinctly different from transanal endoscopic microsurgical (TEM) full thickness excision used for T1 rectal tumours.[16] Early colonic tumours involving only the mucosa or with minimal submucosal involvement (<500–1000 microns) is associated with very low risk of lymph node involvement. Other factors such as lymphovascular invasion, tumour grade are also predictors of lymph node involvement.[17–19] Lesions demonstrating favourable histopathologic criteria are potentially suitable for endoscopic resection. Some have suggested that lateral spreading mucosal tumours, tumours associated with fibrosis, ulcerative colitis and lesions incompletely resected by EMR are suitable for ESD.[20] Prevalence of these suitable lesions is low.[21] However, with the introduction of colon screening programmes, the incidence of detection of early colonic cancer is likely to increase. A meta-analysis of 25 case series of EMR for colonic polyps reported curative en bloc resection of 58.7%. This is superior to conventional polypectomy snare technique.[22] ESD is especially useful in large lesions. A meta-analysis of ESD in resection of colonic neoplastic lesions (including carcinoid tumours) reported a margin free en bloc resection rate of 88% and a complication rate of 1%.[23] Long term recurrence and survival data is required. Special consideration has to be paid to colonic endoscopic resection. Unlike the stomach, the colon is long, tortuous, thin walled and has multiple haustrations.[24] Paradoxical movement of the endoscope due to looping can make resection in the right colon difficult to perform. ESD for colonic lesions can potentially be more technically demanding than ESD for gastric lesions.

Another recently introduced advanced endolumenal technique is peroral endoscopic myotomy (POEM) for the treatment of achalasia. The concept of endoscopic oesophageal transmucosal myotomy is first proposed in 1980.[25] POEM differs in that it aims to divide only the circular muscular layer within a submucosal tunnel. It is hoped that this modification can minimize the risk of mediastinal contamination in the event of oesophageal perforation.[26,27] Several case series with a total of 81 patients have demonstrated that it is effective in reducing dysphagia symptom score and resting lower oesophageal pressure among patients with achalasia.[28–32] However, these series, performed by enthusiasts, at most report a follow up period of three months. Long term follow up studies are needed. An animal study suggested that POEM may reduce lower oesophageal sphincter pressure by a lesser degree when compared to open Heller's myotomy. However, there was no difference in distensibility as measured by the EndoFLIP device.[33] Clinical trials are needed to compare POEM efficacy with that of the standard Heller's myotomy.

The aforementioned innovative endolumenal techniques remain difficult to perform. Currently, published case series of these techniques uses either single or dual channel conventional flexible endoscope. An endoscopic multitasking platform with improved instrument manoeuvrability can potentially make these techniques easier to perform.[34] Increased uptake of these techniques can also make validation studies easier to perform. It is easy to imagine that other very common acute general surgical emergencies such as perforated duodenal ulcers could become amenable to pure endolumenal treatment. For this to be possible and to be accepted, the development of an effective flexible multitasking platform is paramount.

There are obvious challenges to NOTES including instrument access, surgical instrumentation, spatial orientation and luminal closure which are yet to be effectively overcome.[35] The ASGE/SAGES Working Group on Natural Orifice Translumenal recommended that a suitable multitasking platform will be a stable but flexible platform where upon adequate anchorage is provided for traction and tissue dissection, as well as allowing the therapist to control multiple devices.[36] To date, the majority of systems are designed with the aim of performing NOTES intraperitoneal surgery. In this review we aim to review the ever changing landscape of the field of flexible endoscopic multitasking platforms, with specific focus on its visualization method, method of actuation, its limitations and its extent of clinical application.

2. Method

Medline search was performed to identify literature relating to flexible endoscopic multitasking platform from year 2004–2011 using keywords: "Flexible endoscopic multitasking platforms", "NOTES", "Endoscopic robotic surgery", and specific names of various endoscopic multitasking platforms. Key articles from articles references were reviewed.

3. Summary of various platforms

Flexible multitasking platforms can be classified as either mechanical or robotic. (Table 1) Purely mechanical systems include the dual channel endoscope (DCE) (Olympus), R-Scope (Olympus), the EndoSamurai (Olympus), the ANUBIScope (Karl-Storz), Incisionless Operating Platform (IOP) (USGI), and DDES system (Boston Scientific). Robotic systems include the MASTER system (Nanyang University, Singapore) and the Viacath (Hansen Medical). The DCE, the R-Scope, the EndoSamurai and the ANUBIScope have integrated visual function and instrument manipulation function. The other systems rely on the conventional flexible endoscope for visualization, and instrument manipulation is integrated through the use of a flexible, often lockable, multichannel over-tube called an access device. The advantage of the access device concept is that it allows optics and instrument dissociation. However, it is a less compact