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INTRODUCTION

LAPARO-ENDOSCOPIC SINGLE-SITE SURGERY IN UROLOGY: IS ROBOTICS THE MISSING LINK?

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Laparoscopic surgery has dramatically changed the landscape of operative urology, becoming the approach of first choice amongst surgeons and their patients, for its validated benefits of shorter hospitalization, less postoperative pain and earlier recovery. Recently there has been immense interest in both laparo-endoscopic single-site surgery (LESS) and natural orifice transluminal endoscopic surgery (NOTES) approaches to minimally invasive urological surgery. Since Rané *et al.* [1,2] and Raman *et al.* [3] performed the world's first human LESS nephrectomies in 2007, there have been several presentations and reports validating the feasibility and reproducibility of LESS procedures in urology, most notably led by investigators from the Cleveland Clinic [4]. From these early experiences, it would appear that most extirpative and reconstructive urological procedures performed through conventional multiport laparoscopy can be reproduced via a LESS approach. The single undisputed benefit of LESS is improved cosmesis, constraining trocars or the single-access port to the peri-umbilical site. Whilst Gill *et al.* [5] reported less postoperative pain and discomfort in patients undergoing donor nephrectomy via the single-port laparoscopic approach, Raman *et al.* [6] found no significant difference between single-port and conventional multiport laparoscopic nephrectomy in terms of operative time, mean blood loss, hospital stay or postoperative analgesic requirements.

Nonetheless, there are four significant constraints to LESS that must be overcome before this approach becomes part of mainstream laparoscopic practice. First, costly specialized single-access ports are required to introduce laparoscopic instruments through multiple channels incorporated as part of a larger single port, such as the R-Port™ and Quadriport™ (Advanced Surgical Concepts, Wicklow, Ireland), or the Uni-X™ Single Port (Pnavel Systems, Morganville, NJ, USA) [7]. Second, the close proximity of laparoscopic instruments and camera lens often result in intracorporeal instrument collision, hindering the surgeon from operating dextrously within the operative field. Third, the scope of visibility of the operative field afforded by the camera assistant is also limited, who is restricted in his or her freedom to manoeuvre the camera lens to avoid instrument clashing. Finally, intracorporeal dissection and suturing are also made more challenging by the limited range of movement of the laparoscopic instruments. Commercial articulating or pre-bent instruments have been developed to overcome the spatial constraints of single-port access. These include articulating laparoscopic graspers, shears and needle drivers such as the Real Hand™ (Novare Surgical Systems Inc, Cupertino, CA, USA) and Autonomy™ Laparo-angle™ (Cambridge Endo, Framingham, MA, USA) instruments, which offer seven degrees of freedom at the instrument tip [8,9], but their adoption has so far been limited to selected centres.

Could robotics be the missing link?

The benefits of the da Vinci® robotic System (Intuitive Surgical Inc, Sunnyvale, CA, USA) over conventional laparoscopy include superior ergonomics, optical magnification of the operative field within direct control of the console surgeon, enhanced surgeon dexterity within the field of view, and precision of surgical manipulation with tremor reduction. Its latest state-of-the-art offering, the da Vinci S HD™ Surgical System, integrates three-dimensional high-definition vision capability, providing twice the effective viewing resolution with improved clarity and detail of tissue planes. In addition, the EndoWrist® robotic instruments now have extended reach for multi-quadrant access, with a 50% increase in pitch and yaw range of motion, and four times the working volume [10].

Box *et al.* [11] first reported a hybrid LESS robotic-assisted nephrectomy in a porcine model, wherein they placed the robotic scope through one 12-mm abdominal trocar site, while the right and left arms of the robot were placed transvaginally and transcolonically via 12-mm trocars, respectively. They completed the procedure in 150 min, citing technical difficulties encountered to include robotic arm collisions, limited triangulation with the EndoWrist instruments, and a counterintuitive camera angle. Haber *et al.* [12] adopted a different approach toward robotic NOTES in the porcine model, placing the robotic camera lens and one arm through the umbilicus, with the other robotic arm inserted through the vagina. With the arms in this unorthodox configuration, they have been able to complete over 30 robotic NOTES procedures to date, including dismembered pyeloplasty, partial nephrectomy, and completion nephrectomy (personal communication).

Attempting novel modifications to port and robotic instrument configuration, Kaouk *et al.* [13] reported the first successful series of single-port robotic procedures in humans,

including radical prostatectomy, dismembered pyeloplasty and radical nephrectomy. A robotic 12-mm scope and 5-mm grasper were introduced through a multichannel single port (R-Port), whilst an additional 5-mm or 8-mm robotic port was introduced through the same umbilical incision (2 cm) alongside the multichannel port to facilitate entry of robotic instruments. A salient highlight of these procedures was the improved facility for intracorporeal dissecting and suturing. In their experience of performing both urethrovesical anastomosis and ureteropelvic anastomosis, a continuous running suture creating a watertight closure was easier due to improved robotic instrument articulation and stability. Other unpublished reports of robotic LESS surgeries include prostatectomies by the Montsouris group in Paris, France, and a radical nephrectomy by Menon's group at the Henry Ford Hospital, Michigan, USA, who have named their approach 'single-incision robotic surgery'. In these seminal experiences, the chief constraint to performing robotic LESS has been external robotic arm and intracorporeal instrument collisions.

Several recent innovations in robotic technology promise to overcome these limitations of robotic LESS. First, the current design of the da Vinci robotic cart has been based on the traditional laparoscopic approach of manipulating straight rigid instruments intracorporeally by moving their back handles through a three-dimensional spatial cone. As such, the robotic arms occupy a significant footprint over the sterile field, and external collisions using a single-access port are inevitable. By contrast, the Laprotek system (EndoVia Inc, Norwood, MA, USA, subsequently taken over by Hansen Medical Inc.) uses a curved guide tube to position its instruments intracorporeally. The slave instrument 'motor packs' are mechanically mounted on the existing bed-rails of the operating table, and movements from these motors are then transmitted to the surgical instruments via stainless steel cables. Although not commercially available, its design occupies significantly less space in the sterile field, reducing collisions between the robotic instruments and camera [14,15]. Dachs and Peine [15] recently proposed confining extracorporeal movement of the robotic arms to a line instead of a cone, designing robotic instruments with two movable joints within the body that could permit six degrees of freedom of movement without requiring corresponding external pivoting motions. Unconstrained by needing to pivot about the port side, these robotic instruments could be easily mounted on a streamlined mechanical arm which supports its linear track to deliver comparable intracorporeal dexterity and precision. Progress in these directions could eventually lead to elimination of robotic instrument collisions.

Another approach to overcome the limited field of view encountered during LESS could be the use of microelectrical mechanical systems (MEMS) technologies. Rentschler *et al.* [16] from the University of Nebraska first reported the use of miniature *in vivo* adjustable-focus camera on wheeled robots to augment visual feedback to surgeons during laparoscopic cholecystectomy in a canine model. These microrobots had sufficient traction to move over slick, deformable abdominal viscera without causing injury. The same investigators subsequently designed a fixed-base pan-and-tilt camera robot that permitted forward tilting at 45° [17]. Joseph *et al.* [18] recently reported their collaborative experience with both these prototypes in performing laparoscopic prostatectomy and laparoscopic nephrectomy in a canine model. Lehman *et al.* [19] showed the feasibility of using multiple miniature *in vivo* robots for augmenting spatial orientation, together with a conventional upper gastrointestinal endoscope to broaden the scope of NOTES procedures in a porcine model. These feasibility studies showed the significant potential for eventual wireless *in vivo* robotic sensors to provide real-time multi-angle images of the operative field, overcoming the problem of limited field of view during LESS.

A third arena of technological advance has been the field of flexible robotic instruments. Peine *et al.* [20] from Purdue University have been working to develop an endoluminal robotic system comprising a camera lens with two adjacent robotic instruments each having at least six degrees of freedom, plus an end-effector gripping action. Redressing the technical limitations of their initial design based on the ViaCath System (EndoVia Medical, Norwood, MA, USA), these investigators proposed a second-generation flexible endoluminal robotic system and instruments to improve kinematic instrument control and precise manipulation. These designs, hitherto customized for NOTES procedures, have inherent potential for modification to facilitate robotic LESS.

Given the da Vinci system's numerous advantages over conventional laparoscopy and its increasing adoption by urologists worldwide, it is natural to expect robotic LESS to be the next frontier of advance in minimally invasive urology. We look forward to its development with great interest.

CONFLICT OF INTEREST

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Abbreviations: **LESS**, laparo-endoscopic single-site surgery; **NOTES**, natural orifice transluminal endoscopic surgery.

PAYMENT BY RESULTS: FINANCIAL IMPLICATIONS OF CLINICAL CODING ERRORS IN UROLOGY

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INTRODUCTION

The introduction of payment by results (PbR) to the UK National Health Service in 2004 has resulted in a system whereby the amount of revenue a surgical department receives is directly related to the type and number of admissions/procedures in that department. The accuracy of PbR data is thus extremely important to ensure that departments are appropriately remunerated for the work they carry out. Clinical coding is the process by which patient admissions are converted into nationally set tariffs under the PbR system. In addition to the financial role, clinical coding data form a significant contribution to the Hospital Episode Statistics collected by the Department of Health. These data provide information on diagnoses, procedures, interventions and length of stay, used in planning healthcare resources.

For every completed patient episode, a healthcare resource group (HRG) code is assigned by combining the International Classification of Disease (ICD-10) codes for the patient's primary diagnosis and comorbidities, with the Office of Population Censuses and Surveys version 4.0 (OPCS-IV) code of the primary procedure performed. Each HRG code attracts a nationally set tariff at which the Trust is remunerated. The final amount of money received by the department is also influenced by the patients' age, length of stay and the market-forces factor that reflects regional differences in the cost of healthcare provision [1,2]. From a financial perspective, the primary diagnosis very rarely affects the final urological HRG (and therefore the tariff received by the Trust) as this largely depends on the primary procedure and the presence of specific comorbid conditions. This is in contrast to medical coding, where the patient's diagnosis is the primary determinant of the HRG tariff [3]. Previous studies [4,5] have identified a high level of inaccuracy in the coding of urology activity (>30%). It has been suggested that this level of coding error could result in annual losses of up to £6 million in a large orthopaedic department [1]. However, to date the financial implications of these coding errors in urological practice have not been investigated. The aim of this study was to determine the error rate of clinical coding for a urology tertiary referral centre, to identify causal factors and calculate the amount of revenue lost.

METHODS

One investigator (I.B.) met with the Trust's urology clinical coders to develop an understanding of the principles of clinical coding needed to review current practice. A random selection of 500 case-notes from elective, day-case and emergency admissions during a 3-month period (September to November 2007) were reviewed retrospectively. The notes reviewed represented ≈75% of the overall departmental workload during that period.

The patient's primary operative procedure and comorbidities were coded by I.B. according to ICD-10 and OPCS-IV HRG classifications, with no previous knowledge of the codes assigned by the clinical coders.