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INTRODUCING A ROBOTIC LIVER SURGERY PROGRAM INTO AN NHS HPB SERVICE

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ABSTRACT

Our study was to evaluate the introduction of a Robotic HPB service into an NHS service. Robotic training courses were attended first alongside International mentorship and proctoring. Prospectively collected database was created recording intra-operative and post-operative events for all patients having robotic liver surgery during 30month period. 11 cholecystectomies, 5 fenestrations of massive liver cysts and 5 left lateral liver resections were documented. Mean operating times were 90min (range40-145), 142min (90-240) and 252min (165–345) respectively. There were no intra-operative complications, conversions to open and transfusion. Median length of hospital stay was 1day (range1-5), 1day (1-10) and 4 days (3–6) respectively. One patient experienced a post-operative complication; grade B bile leak after fenestration of a cyst. There were no readmissions and no mortality. The introduction of a robotic liver surgical program in the UK NHS is a safe, feasible step allowing continual evolution of minimally invasive liver surgery.

Introduction

A minimally invasive approach to liver surgery was introduced 25 years ago [1] and now is considered routine in high volume HPB units. Laparoscopic liver resections (LLR) have increased enormously in recent years [2,3], representing up to the 80% of all liver resections performed in some reported series [3]. The well recognised advantages of minimally invasive liver surgery include less respiratory complications [4], faster recovery to normal activities [5], reduced post-operative pain [6], shorter hospital stay [4], less intraoperative blood loss [4,5,6] and lower rates of incisional hernias [4]. Indeed the Louisville Statement of 2008 recommended a laparoscopic approach for liver lesions less than 5 cm in diameter and for those tumours positioned in the anterior and left lateral segments of the liver (e.g.g2,3,4,5 and 6) [2]. In 2014 experts in Marioka [7] agreed that LLR should be standard practice for these indications whereas for major liver resections (full right and full left) good evidence was still not supportive with no reported randomized controlled trials.

Technical limitations of laparoscopy and the peculiarities unique to liver surgery still make LLR less popular. The propensity for the liver to bleed, the precision required to dissect the hilum, biliary reconstruction, access to the inferior vena cava, controlling the major hepatic veins and access to the posterior segments of the right liver, all deter less experienced surgeons from starting a laparoscopic liver surgery program. Other considerations include the restricted movement performed by rigid laparoscopic instruments with a fixed fulcrum at the port site, the difficulty in rapid suturing particularly in the presence of bleeding and the lack of 3D perception.

With these considerations in mind robotic liver surgery has the potential to overcome some if not all of these disadvantages over conventional laparoscopic liver surgery [8], but the cost is potentially prohibitive.

Aim

A robotic surgery program was introduced in our centre with the specific aim to maximum its use amongst different specialties; these include urology, cardiothoracic, ENT and hepatobiliary surgery despite limited UK experience in some of these specialties. Nevertheless this still limits the use to 2-3 exposures per month for robotic procedures within HPB. The aim of this study was to describe the feasibility of introducing a robotic liver surgery program in a UK HPB tertiary referral NHS Hospital.

Methods

The first robotic procedure performed in our hospital (Freeman Hospital, Newcastle upon Tyne Hospitals NHS Foundation Trust) was a radical prostatectomy completed in July 2013. 500 robotic procedures were performed within 19 months and 1000 completed by 28 months. Robotic procedures regularly carried out at the Freeman Hospital included: prostatectomies, neo-bladder cystectomies, anterior rectal resections, lung lobectomies, total hysterectomies and transoral oropharingectomies. During the development of our program all robotic procedures had an enhanced tariff to make its use more financially attractive.

Training

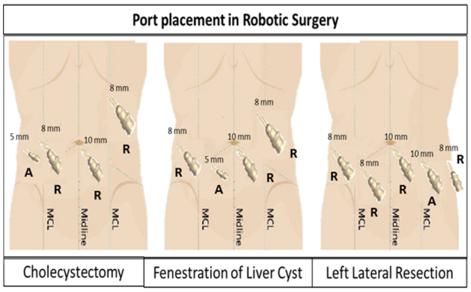
Surgeons with an interest in laparoscopic liver surgery attended a robotic human cadaver course in Paris in November 2013. Our unit has significant previous experience of laparoscopic liver resection having introduced the UK's first human cadaver laparoscopic liver course in 2011 and reporting a series of 100 previous liver resections in 2014. The goals of the robotic course were to understand the different ergonomics, instrumentation and parenchymal transection devices for robotic liver surgery [9].

Between the end of 2013 and the beginning of 2014 visits to specialist HPB robotic centres in Europe were undertaken to observe robotic liver surgery along with mentorship from advanced proctors returning to our centre for our first cases. As reported by others [10], our surgical team gained their initial experience by performing cholecystectomy as the index operation, the first being performed in December 2013. After a series of 11 cholecystectomies more complex procedures were then introduced.

Analysis
A retrospective analysis of a prospectively collected cohort was performed. These included robotic cholecystectomies, fenestrations of liver cysts and left lateral liver resections. All procedures were performed between December 2013 and June 2016. With the exception of cholecystectomy patients, all patients were discussed in a multidisciplinary team (MDT) meeting, which included surgeons, oncologists, radiologists and histopathologists. Outcome agreements were achieved for every patient, describing the type of resection and the approach (open or laparoscopic or robotic). Complications were recorded. Conversion to open procedure was defined as the necessity to perform a laparotomy at any moment during surgery.

Set Up
All surgical procedures were performed using the third generation Da Vinci Si model (Intuitive Surgical, Sunnyvale, USA). All 3 robotic arms were initially used during each operation along with either 1 or 2 assistant ports either 5 mm or 10mm but during the evolution of our program sometimes only 2 arms were used. An additional robotic arm was used for the camera. This port was usually positioned at the level of the umbilicus. Two robotic arms were used as working ports and the third arm as a retractor. A further laparoscopic port could be used by the assistant for aspiration, clipping or stapling. Port positioning varied according to the type of resection [Figure 1].

[Figure 1] Ports placement in Robotic Surgery (R: Robotic ports, A: Assistant ports)



Parenchymal liver transection was adapted to a non CUSA technique using bipolar robotic scissors, a robotic compatible harmonic scalpel (EthiconEndo-Surgery,Cincinnati,OH), Ligaclips, Tissuelink device (Medtronic) and a stapling device (Echelon Flex™ Endopath® Staplers). Fenestration of liver cysts was performed using the Da Vinci sealer device (EndoWrist® One™ VesselSealer for the DaVinci® Si™, Intuitive Surgical) [Figure 2].

[Figure 2] EndoWrist ® One ™ Vessel Sealer for the da Vinci ® Si ™, Intuitive Surgical.

Haemostasis was achieved by bipolar coagulation and/or suture ligation. Control of the hepatoduodenal ligament using a snugger or equivalent was never placed. The surgical specimen was removed with an Endo catch II bag (Endo Catch Tm, Covidien) from either a supra-pubic incision or extended port site incision.

Recovery
A postoperative enhanced recovery program was adopted. All patients started drinking the same day of surgery and were allowed to eat a normal diet on the first post-operative day (POD)1. All liver patients, although transferred to High Dependency Unit soon after surgery, were mobilized and encouraged to perform physical exercise by a physiotherapist on the first post-operative day. Neither the nasogastric tube or urinary catheters were left after the first postoperative day. Epidural anaesthesia was never used.

Statistics
Data were recorded, the mean was calculated to give an indication of the central tendency of the sample and the range of interval was reported to describe the deviation from central tendency. Percentage were obtained to give information about the proportion of the all dataset represented. The median was used for data without a normal distribution. The Student's T-test was adopted to statistically assess the differences in the operating time between the first 5 laparoscopic cholecystectomies and the last 5 performed; a p-value < 0.05 was considered statistically significant.

Result
Eleven solitary robotic cholecystectomies were performed, 2 additional cholecystectomies were performed in the liver cyst patients. 73% of patients were female (median 51 years, range 29-83). Five robotic liver cysts fenestrations were also performed, 80% were female (median age was 62, range 47-70) and 5 robotic left lateral liver resections, 20% were male (median age was 51, range 43-75).

The majority of robotic cholecystectomies (82%) were performed for symptomatic gallstones with a history of cholecystitis or biliary colic; 7 were performed during an elective admission, and 2 as emergencies. The mean operative time for a robotic cholecystectomy in this series was 90min (range between 40 and 145min) [Table 1]. In this group of patients the median docking time (time from patient entering the OR from the anaesthetic room to first port placement) was 30min (range between 15 and 50min). Discrepancies in docking times were always due to training and education of other theatre staff.

Table 1 Robotic cholecystectomy (Literature review).

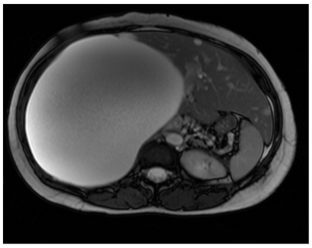
Study	Year	No. of patients	Mean duration of surgery (min)
Kim et al	2002	10	57
Cadičre et al	2001	48	70
Vidovszky et al	2006	48	77
Giulianotti et al	2003	66	85
Shiva et al	2009	16	91
Hanisch et al	2001	5	95
Ruurda et al	2002	35	97
Hashizume et al	2002	6	118
Heemskerk et al	2005	12	150
Perez et al	2003	20	152
Talamini et al	2002	8	167

There were no postoperative complications. The median length of hospital stay was 1 day (range between 1 and 5 days). One patient stayed in hospital 5 days after surgery because of the need for a post-operative ERCP for removal of a CBD stone. From a technical point of view port placement is similar to a conventional laparoscopic cholecystectomy with the exception that the xiphisternal port is placed lower and in the mid-clavicular line on the patients left side rather than in the midline [Figure1]. This is only done to accommodate the robotic arms but does not hinder dissection of Calot's triangle.

Liver cyst fenestrations were performed because of abdominal symptoms [Figure 3].

[Figure 3]

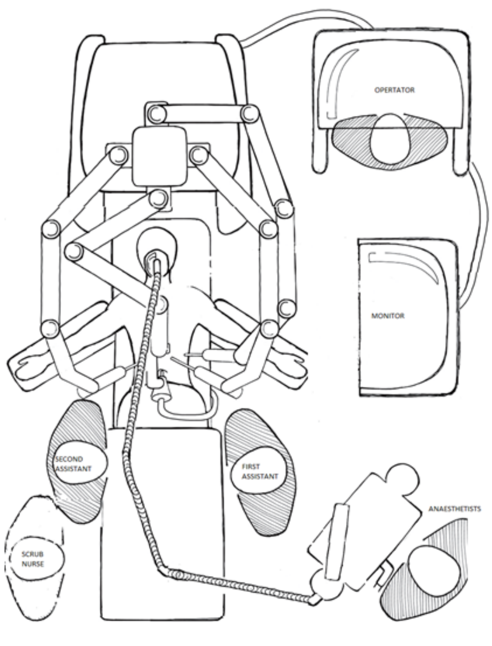
MRI Liver of a Large liver cyst (18x18x24 cm) of a patient who underwent an uneventful Robotic fenestration.



In two (40%) patients a cholecystectomy was also performed. A preoperative CT and/or MRI liver were performed in all cases to exclude mural nodules, septations and potential communication with the biliary tree. Median liver cyst diameter was 12cm (range between 6 and 24cm). The median operative time was 90min (range 90-240), whereas the median docking time was 20min (range between 15 and 30). Mean intraoperative blood loss was 120 ml (range 50-200ml), none required a blood transfusion. One patient (the first patient) developed a post-operative bile leak grade B (ISGLS). This patient was treated with ERCP and a biliary stent. This patient remained in hospital until day 10 but all the remaining patients were discharged on the first post-operative day.

Two liver resection patients had synchronous colorectal liver metastasis (CRLM), the other three had indeterminate liver lesions with suspicious features. Postoperative histology showed that one of these patients had a well differentiated hepatocellular neoplasm of uncertain malignant potential (HUMP, 95mm in diameter), the other had a benign involuted cystic lesion (24x15mm) and the last an angiomyolipoma with an epithelioid component (36x30mm).

Both patients with CRLM underwent robotic left lateral sectionectomy after a previous laparoscopic anterior rectal resection to remove the primary along with adjuvant chemotherapy beforehand. The median duration of a left lateral sectionectomy was 240min (range between 165 and 345min) and the median docking time 10min (range 5-45min). There were no conversions and no intra-operative or post-operative complications, mean blood loss was 250ml (range between 50ml and 700ml) again none requiring a blood transfusion. The median length of stay was 4 days (range 3 and 6 days). Only one patient stayed in hospital for more than 4 days after surgery due to social circumstances delaying discharge. All liver resections were R 0. Port placement and theatre arrangement during a robotic left lateral resection are illustrated respectively in Figures 1 and 4. None of the 21 patients undergoing HPB robotic procedures were readmitted after discharge and the mortality rate was 0%.



[Figure 4] Theatre arrangement during a Robotic Left Lateral Sectionectomy.

Discussion

During the last 5 years there has been increasing interest in robotic liver surgery because of the perceived superior versatility of robotic technology which may overcome some of the limitations of the conventional laparoscopic approach [8]. However interest in the UK has been limited and previously unreported. The largest reported series includes 183 robotic hepatectomies and represents the only centre in the world documenting more than 100 robotic liver resections [11]. A review of 19 robotic series published in 2013, described a mean of 13 robotic liver resections per unit [12]. However the earliest experience of HPB surgery using robotic technology was reported by Gagner, who reported the first robotic cholecystectomy in 1994 [13].

The Da Vinci system developed by Intuitive was approved by the FDA in 2000, since then several centres have published robotic training programs [9]. There are no current guidelines on how to introduce a robotic program in an established HPB centre and as yet is unreported in the UK. It can never be overstated enough that it is vital to practice safe surgery and it is our belief that surgeons should have demonstrated adequate experience with conventional laparoscopic techniques supported by an appropriate training program alongside expert mentorship who attends the first procedures in any new program. A catastrophe in the early stages of any program would be a disaster not only for the operative surgeon and centre but also public perception of a new technique [14].

No data are available about a learning curve in robotic liver resection due to the small number of series performed to date.

Although there is no scientific evidence as to which surgical procedure should be used as the index operation for HPB robotic surgery, the general attitude of several authors [10] is to start performing laparoscopic cholecystectomies first. It is not our intention to offer robotic cholecystectomy as a routine procedure and was only done to become familiar with robotic technology. The general view [10] is that 10 robotic cholecystectomies can be considered a reasonable number to gain confidence and experience and thereafter consider more complex procedures. This is not absolute as an advanced laparoscopic surgeon who regularly performs liver and pancreas resections would not regard a cholecystectomy as particularly challenging and may decide to advance without having tried any at all. Nevertheless it must not be forgotten that a catastrophic error could occur in any first case and in out litigious society no previous experience maybe difficult to defend in court.

In our centre 11 robotic cholecystectomies were performed before introducing other HPB surgical procedures. An overall assessment of the operative time (OT) of our 11 robotic cholecystectomies showed a reduction in the time spent to perform the last operations. The mean OT of the first 5 cholecystectomies was 105 min, whereas the mean OT of the last 5 was 70min (T-test, t-value = 1.90516 and p-value = 0.046). There is no doubt this demonstrates progress and a learning curve.

Fenestrations of massive liver cysts were considered to be the next case advance although there is limited literature to use as a comparator. In our series four of five patients were discharged on post-operative day 1 without any complication. One patient, our very first patient developed a bile leak which required ERCP and biliary stenting. The cyst wall was resected using the Endo-Wrist One Vessel Sealer [Figure 2] for the Da Vinci Si system (Intuitive Surgical) as described by others [15]; Nota et al [15] described 2 uneventful robotic fenestrations of giant liver cysts performed with the vessel sealer. The Endo-Wrist One Vessel Sealer was initially introduced in 2012 as an advance to the Da Vinci Harmonic Ace (Ethicon EndoSurgery). The Endo-wrist sealer combines full articulation of a robotic device along with a sealing technology with bipolar coagulation. Studies have shown that sealing can safely sustain burst pressure well above 3 times the systolic blood pressure on vessels up to 7 mm in diameter [16]. Nonetheless there is limited information regarding sealing of bile ducts. All 5 robotic fenestrations of liver cysts were performed with the Endo-Wrist One Vessel Sealer but because of our first case having a bile leak, more recent practice is to perform a running suture along the wall remnant when bile ducts are seen. With the 3-D visualisation small bile ducts are easy to see which can then be over-sewn. Since this change of practise in our last 9 cases no further bile leaks have occurred.

Five robotic left lateral liver resections were then performed. The mean OT was 240min. A recent systematic review of Ho et al [12] reported a mean operating time ranging from 200 to 507 minutes. More recently Chen et al [11] published the largest series of robotic liver resections describing a mean OT of 434min (range 142 and 805min). However only 50% of operations included in this series were represented by minor liver resections. In our series a progressive decrease in the length of OT was observed 345 (first case) to 165 minutes (fifth case) as well as hospital stay from day 6 (first case) to day 3 (last 3 cases).

The mean intraoperative blood loss (IOBL) was 250ml. Ho et al [24] describe a mean IOBL ranging from 50 to 660ml. Chan et al reported mean blood loss of 195ml (range 50-2000ml). Two other series of robotic liver surgery were recently published, comparing the results of robotic surgery with the laparoscopic approach; Troisi et al [17] described 40 robotic resections with a mean intra-operative blood loss of 330+/-303ml, Tsung et al [18] reported 57 cases with a mean blood loss of 200+/-71.8ml. In our series only 1 patient had blood loss exceeding 500ml. In this patient the indication for a left lateral resection was a 9.5cm mass in the left liver. The overall conversion rate reported in the review of Ho et al [12] was 4.6%. Recently published large series [17] described a conversion rate of 20%. In our series of liver resections there were no conversions to open surgery and no postoperative complications. Complication rates have been reported to be up to 20.3% but these mainly relate to larger resections [12]. The mean length of hospital stay was 4 days consistent with others. Whereas a recent Italian multi-centre study [19] patients stayed in hospital for a mean of 10.5 +/- 4.5 day but all had a major liver resections which is not a good comparison as these are more complex resections. In the review of Ho et al the mean postoperative hospital stay ranged from 5.5 to 11.7 days. Lai et al published a series of 42 robotic resections for HCC, the R0 resection rate was 93% and the 2 year disease-free survival rate was 74% [20]. All lesions of our patients were completely resected. At 12 months follow up there were no recurrences.

One of the problems relating to robotic liver surgery is the technique of parenchymal transection [21]. The most commonly used technique in the UK is CUSA dissection [22]. This is more difficult to institute for robotic surgery as there is no Da Vinci CUSA device. Theoretically it can be used as a hybrid technique but there is limited space at the table when the robotic arms are docked making it too cumbersome. The assistant would also have to be the primary operator which is far from ideal if he is not experienced. Because of these limitations we have adopted using the Tissuelink device (Medtronic) and the harmonic scalpel. The endo-wrist sealer has a blunt tip making it more difficult to separate the liver parenchyma but it could be used for larger blood vessels and bile ducts and for structures beyond 7mm we would recommend suturing [21].

In our experience the introduction of a robotic liver surgical program in the NHS is a safe and feasible step for a high volume tertiary referral HPB centre. The versatility of the Da Vinci Si Robotic Surgery System, the objective technical challenges characterising the liver surgery and the increasing orientation of the HPB surgeon towards minimally invasive procedures makes the robotic approach a natural evolution with some advantages over the conventional laparoscopic approach. The expected reduction in costs as technology advances should motivate the development of more Robotic HPB programs and we advocate a well-structured, stepwise program for its safe introduction.

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