Short-term outcomes of da Vinci Xi versus Si robotic systems for minor hepatectomies

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Abstract. Background and aim: In the recent years, robotic technology has been drastically improved and the last generation of robotic platforms is hardly comparable with the earlier ones. The present study aims to investigate the short-term outcomes of minor hepatectomies performed with da Vinci Xi surgical system vs. Si surgical systems. Methods: Consecutive patients operated on between 2013 and 2020 in two referral centers were selected if underwent elective robotic minor hepatectomy (<3 consecutive segments) for primarily resectable benign or malignant lesions. Operative, postoperative, and cost outcomes were compared between the two groups by univariate and multivariate analyses. Results: Eighty-nine patients were selected (64 in the Si system vs. 25 in the Xi system group). Wedge resection was the most performed procedure (49.4%). The Si system group showed a significantly greater total incisional length (+8.99 mm; p<0.0001) related to the use of a higher number of robotic/laparoscopic ports. Pedicle clamping was more frequent in patients operated on by the Xi system (80% vs. 21.9%; p<0.0001) but without group differences in ischemia duration when clamping. A significantly shorter time to flatus (-0.75 days; p=0.015) was observed for patients operated on by the Xi system, whereas no group differences were found for operative time, conversion rate, estimated blood loss, postoperative complications, mortality, use of analgesics, and costs. Conclusion: The da Vinci Xi system represents a technological advancement with a potential clinical relevance, although further studies are needed to clearly detect the clinical impact of the use of this robotic platform in liver surgery. (www.actabiomedica.it)

Key words: robotic surgery, minor hepatectomy, da Vinci Xi system, da Vinci Si system, minimally invasive surgery, liver tumor

Introduction

Laparoscopic surgery for liver resection was first described in 1991(1); ever since, laparoscopy has been largely applied and is nowadays considered as a safe and effective approach to the management of surgical liver disease (2, 3), even in elderly patients (4-6). More recently, robotic surgery has been proposed to overcome laparoscopic limitations and offer to surgeons an advanced technology with improved visualization and dexterity (7-11). Perioperative outcomes of robotic surgery have been compared with laparoscopy for several liver surgery procedures, including left lateral sectionectomy, major hepatectomies (resection of ≥3 Couinaud liver segments), and minor hepatectomies (7, 9-15). The majority of these single center
The present analyses were conducted retrospectively on patients’ records obtained from prospectively maintained databases of two referral hospital centers: the Henri Mondor University Hospital of Creteil (France) and the Miulli Hospital of Acquaviva delle Fonti, Bari (Italy). Consecutive patients undergoing minor hepatectomy by da Vinci Xi or Si robotic platforms (da Vinci Intuitive Surgical Inc, Sunnyvale CA, USA) between September 2013 and September 2020 were selected if the following criteria were fulfilled: adult patient (>18 years) operated on in elective surgery; benign or malignant liver diseases; primarily resectable lesion in a single procedure; absence of metastatic extra-hepatic disease. Minor hepatectomy was defined as the liver resection of less than 3 consecutive liver segments (24-26). Both centers were equipped with the two robotic platforms; the choice between the Xi and Si robot was based upon platform availability within each center.

This is retrospective study dealing exclusively with anonymous clinical record data routinely collected in health databases. This research complies with the MR004 regulation; it was declared to the National Commission for Data Protection and Liberties (CNIL: 2210699). All personal data were collected after informing the involved patients and were treated in conformity to the ethical standards of the Helsinki Declaration.

The study was reported following the STROBE checklist (27).

Surgical procedure

Procedures were performed by 4 surgeons (RM, NdeA, GB, DS) operating in pairs all experienced in minimally invasive liver surgery. In all cases, the aim of the surgical treatment was to achieve a complete macroscopic resection of the lesion with a remnant liver volume to body weight ratio ≥ 0.5%(28). Intraoperative liver ultrasound was used systematically to confirm the number and size of the lesions, define their relationship to the major intrahepatic vascular structures, and rule out the presence of occult metastases. Upon completion of the liver resection, Doppler ultrasound was performed to assess vessel patency in the remnant liver. In selective cases, indocyanin green fluorescence was used for real-time visualization of biological structures (29).

The patient is placed in reverse Trendelenburg (>15°) supine position, except for posterior section
resections, where the patient is placed in left lateral decubitus position. Patient’s arms lay along the body and legs are open. The assistant surgeon stands within the patient’s legs. The table height is set as low as possible before docking the robot.

For the da Vinci Si robot, 4 robotic ports were used, including a 12-mm peri-umbilical port for the 30° robotic camera and three 8-mm robotic working ports placed in a semi-circular fashion. One to two additional laparoscopic ports (12-mm and 5-mm ports) were used for intraoperative ultrasound, sutures, and laparoscopic stapling devices. They were placed either on the same line of the robotic working ports on the left quadrant or at 5 cm below this line according to the hepatic lesion location. The robot was docked over the patient’s head (Figure 1). As robotic energy devices, Harmonic Scalpel (Ethicon Endosurgery Inc), Endowristed monopolar scissors and Endowristed bipolar forceps (Maryland) were used. For difficult dissection, additional laparoscopic energy devices were used, such as LigaSure™ technology (Medtronic, Minnesota, USA) or ultrasonic dissector (Cavitron). Any vessel larger than 3 mm was secured by laparoscopic Hem-o-lok clips (Teleflex Medical, Research Triangle Park, NC, USA) or mechanical stapler (Covidien, Mansfield, USA).

Minor hepatectomies were carried out with 3 robotic working ports, one robotic camera port, and one or two laparoscopic assistant ports.

For the da Vinci Xi robot, four 8-mm robotic ports were used, including the robotic camera, which was placed in the umbilicus. The other ports were placed 8 cm away from each other, on the right (2 ports) and left (1 port) from the umbilical port, on a diagonal line perpendicular to target anatomy and surgical work volume. The 12-mm assistant port was placed left lateral, at least 7 cm from the left robotic port, or 8 cm below the robotic port diagonal line, on the right or left quadrant according to target anatomy. The robot was docked on the right side of the patient (Figure 2).

Minor hepatectomies were carried out with 4 robotic ports (including the robotic camera port), and one laparoscopic assistant ports.

As robotic energy devices, Endowrist Vessel Sealer (da Vinci Intuitive Surgical Inc, Sunnyvale CA, USA), Endowristed monopolar scissors, and Endowristed bipolar forceps (Maryland) were used. If needed, dissected vessels were secured by robotic Hem-o-lok clips (Teleflex Medical, Research Triangle Park, NC, USA) before section or by Endowrist robotic vascular stapler (45 mm).

A Pringle maneuver was done in an intra-corporeal or extra-corporeal fashion, according to the surgeons’ preference. In case of extra-corporeal Pringle maneuver, a 5- or 3-mm additional port was used by placing it at the site of the Pfannenstiel incision or along the axillary line in the right flank (30, 31). The surgical specimen was retrieved from the Pfannenstiel incision. All cases were purely robotic procedures.

**Study Outcomes**

Patient’s demographics, clinical characteristics, surgical indications, and types of liver resection were...
Costs were specifically estimated for liver resections by identifying the type of intervention/indication on the Groupe Homogene de Malade (GHM) database, with specific codes for hepatectomy for malignant tumor (07C09) and for hepatectomy for benign tumor (07C10). The costs associated with the purchase and maintenance of the robotic platforms were not considered.

Statistical Analysis

For bivariate two-sided comparisons between the da Vinci Xi and the da Vinci Si groups, Chi-square test or Fisher’s Exact test and Mann–Whitney U test were used for categorical and continuous variables, respectively. Continuous variables were expressed as mean and standard deviation (SD) or median and range, whereas categorical variables were expressed as frequency (n and %). Mixed model ANOVA was used for postoperative outcomes expressed as continuous variables and costs, with the type of robotic platform as fixed factor and the center as random factor. The assumption of homogeneity of variance was checked by Levene’s test. Binary logistic regression models were performed for outcomes expressed as categorical variables. Pre-operative patient- and tumor-related variables that may impact on the study outcomes were entered in the models as covariates, including: age, sex, BMI, number of lesions, tumor size, tumor location, indication for surgery, difficulty index, and center. A
p value <0.05 was considered to be statistically significant. Statistical analyses were performed with SPSS (Statistical Package for Social Science, IBM SPSS Statistics, Version 22 for Macintosh).

Results

Between 2013 and 2020, 92 consecutive patients underwent liver resection by using robotic Si or Xi systems. Of these, 89 were minor hepatectomies and were selected for the present analyses, including 64 (79.1%) procedures carried out by the da Vinci Si system and 25 (28.1%) by the da Vinci Xi system (Figure 3).

When comparing the demographics and clinical characteristics of the two groups of patients, significant differences were observed for the indication for liver surgery, the location of the liver lesion, the mean size of the largest nodule, and the type of liver resection (Table 1). Particularly, patients operated on by the Si system presented with a higher proportion of hepatocellular carcinoma (59.4% vs. 32%) and a lower proportion of colorectal cancer metastasis (14.1% vs. 52%) compared to patients operated on by the Xi system (p=0.025). The mean size of the liver lesion was significantly larger in patients operated on by the Si system than the Xi system (p=0.001) with the most prevalent location being the left lateral segments.

Consequently, significant differences were observed in the type of procedure performed (p<0.0001), although wedge resection was the most commonly performed in both groups representing 51.6% of liver resections in the Si system group and 44% of liver resections in the Xi system group (Table 1).

Concerning the operative and postoperative outcomes (Table 2), the Si system group was associated with a significantly greater total incisional length (estimated at +8.99 mm) related to the use of a higher number of ports (p<0.0001). In details, for the da Vinci Si system, 49 (76.6%) procedures were carried out with 6 ports, 13 (20.3%) procedures with 7 ports, and 2 (3.1%) with 8 ports. For the da Vinci Xi system, 21 (84%) procedures were performed with 5 ports and 4 (16%) procedures with 6 ports. Also, the recur to pedicle clamping was more frequent in patients operated on by the Xi system in both the non-adjusted and adjusted model, but the duration of ischemia when clamping was not different between the two groups (adjusted p=0.957). Postoperatively, a significantly shorter time to flatus was observed in patients operated on by the Xi system (estimated at -0.75 day; p=0.015). No differences were found in postoperative complications and mortality at 90 days, as well as for the duration of hospital stay and the use of analgesics.

The cost analysis showed that the costs for the needed instruments/devices (robotic and
Table 1. Demographic characteristics and pre-operative variables of patients operated on by da Vinci Si or da Vinci Xi for minor hepatectomy.

| Variable                                      | Total study population (n=89) | da Vinci Si (n=64) | da Vinci Xi (n=25) | p value |
|-----------------------------------------------|-------------------------------|--------------------|--------------------|---------|
| **Age (yr) [median(range)]**                  | 63 (25-83)                    | 63 (25-83)         | 63 (31-82)         | 0.898a  |
| **Age >65 (yr) [n (%)]**                      | 36 (40.4)                     | 25 (39.1)          | 11 (44)            | 0.811b  |
| **Gender (F/M) (n)**                          | 32/57                         | 22/42              | 10/15              | 0.631b  |
| **BMI (kg/m²) [median(range)]**               | 26.26 (18-36.73)              | 26.19 (18.82-36.73)| 27.5 (18-36)       | 0.243a  |
| **Obesity (BMI > 30 kg/m²) [n (%)]**          | 18 (20.2)                     | 13 (20.3)          | 5 (20)             | 1b      |
| **ASA score (I/II/III) (n)**                  | 7/44/38                       | 5/31/28            | 2/13/10            | 0.948c  |
| **Comorbidity >1 [n (%)]**                    | 30 (33.7)                     | 21 (32.8)          | 9 (36)             | 0.806b  |
| **Diabetes [n (%)]**                          | 16 (18)                       | 12 (18.8)          | 4 (16)             | 0.81b   |
| **Cardiovascular diseases [n (%)]**           | 31 (34.8)                     | 19 (29.7)          | 12 (48)            | 0.138b  |
| **Kidney diseases [n (%)]**                   | 2 (2.2)                       | 1 (1.6)            | 1 (4)              | 0.485b  |
| **Pulmonary diseases [n (%)]**                | 13 (14.6)                     | 10 (15.6)          | 3 (12)             | 1b      |
| **Smoking [n (%)]**                           | 17 (19.1)                     | 13 (20.3)          | 4 (16)             | 0.770b  |
| **Previous abdominal surgery [n (%)]**        |                               |                    |                    |         |
| • Open surgery                                | 20 (22.5)                     | 16 (25)            | 4 (16)             | 0.413b  |
| • Laparoscopy                                 | 20 (22.5)                     | 12 (18.8)          | 8 (32)             | 0.257b  |
| **ALT >40 UI/L [n (%)]**                      | 8 (9)                         | 6 (9.4)            | 2 (8)              | 1b      |
| **AST >40 UI/L [n (%)]**                      | 9 (10.1)                      | 6 (9.4)            | 3 (12)             | 0.707b  |
| **Hypoprotidemia (<30 g/L) [n (%)]**          | 2 (2.2)                       | 2 (3.1)            | 0                  | 1b      |
| **Liver parenchyma [n(%)]**                   |                               |                    |                    |         |
| • Normal                                      | 47 (52.8)                     | 31 (48.4)          | 16 (64)            | 0.624c  |
| • Fibrosis                                    | 5 (5.6)                       | 4 (6.3)            | 1 (4)              |         |
| • Cirrhosis                                   | 32 (36)                       | 25 (39.1)          | 7 (28)             |         |
| • Nonalcoholic steatohepatitis                | 5 (5.6)                       | 4 (6.3)            | 1 (4)              |         |
| **Indication for liver resection [n(%)]**     |                               |                    |                    |         |
| • Hepatocellular carcinoma                    | 46 (51.7)                     | 38 (59.4)          | 8 (32)             | 0.025c  |
| • Gallbladder cancer                          | 1 (1.1)                       | 0                  | 1 (4)              |         |
| • Metastasis from colorectal cancer           | 22 (24.7)                     | 9 (14.1)           | 13 (52)            |         |
| • Metastasis from breast cancer               | 2 (2.2)                       | 2 (3.1)            | 0                  |         |
| • Metastasis from esophagus cancer            | 1 (1.1)                       | 1 (1.6)            | 0                  |         |
| • Focal nodular hyperplasia                   | 4 (4.5)                       | 3 (4.7)            | 1 (4)              |         |
| • Liver hemangiomia                           | 4 (4.5)                       | 4 (6.3)            | 0                  |         |
| • Ciliated hepatic forgut cyst                | 3 (3.4)                       | 2 (3.1)            | 1 (4)              |         |
| • Hepatocellular adenoma                      | 3 (3.4)                       | 3 (4.7)            | 0                  |         |
| • Biliary cyst                                | 2 (2.2)                       | 1 (1.6)            | 1 (4)              |         |
| • IPNBL                                       | 1 (1.1)                       | 1 (1.6)            | 0                  |         |
| **Number of lesions [n(%)]**                  |                               |                    |                    |         |
| • Single lesion                               | 74 (81.3)                     | 55 (85.9)          | 19 (25.7)          | 0.345b  |
| • Multiple lesions                            | 15 (16.9)                     | 9 (14.1)           | 6 (24)             |         |
| **Size of largest nodule (mm) [men(SD)]**     | 28.66 (20.53)                 | 32.98 (22.67)      | 18.13 (6.83)       | 0.001a  |

Table 1 (Continued)
### Table 2. Operative and post-operative outcomes of patients operated on by da Vinci Si or da Vinci Xi for minor hepatectomy.

| Lesion location [n(%)] | Total study population (n=89) | da Vinci Si (n=64) | da Vinci Xi (n=25) | p value |
|-------------------------|-------------------------------|--------------------|-------------------|---------|
|                         |                                |                    |                   |         |
| Posterior Segment (6-7) | 18(20.2)                      | 12(18.8)           | 6(24)             | 0.003c  |
| Anterior Segment (8-5)  | 9(10.1)                       | 6(9.4)             | 3(12)             |         |
| Medial Segment (4-1)    | 11(12.4)                      | 8(12.5)            | 3(12)             |         |
| Left lateral segments (2-3)| 41(46.1)                  | 35(54.7)           | 6(24)             |         |
| Posterior + anterior segments | 4(4.5)                  | 0                  | 4(16)             |         |
| Anterior + medial segments | 1(1.1)                  | 0                  | 1(4)              |         |
| Medial + left lateral segments | 2(2.2)                  | 2(3.1)             | 0                 |         |
| Posterior + medial segments | 1(1.1)                  | 1(1.6)             | 0                 |         |
| Posterior + anterior + medial segments | 2(2.2)              | 0                  | 2(8)              |         |
| Preoperative chemotherapy [n(%)] |                                |                    |                   |         |
| With biological addition | 1(4)                        | 1(8.3)             | 0                 | 0.566c  |
| Without biological addition | 15(60)                     | 7(58.3)            | 8(61.5)           |         |
| Type of liver resection [n(%)] |                                |                    |                   |         |
| Segmentectomy           | 15(16.9)                     | 6(9.4)             | 9(36)             |         |
| Bisegmentectomy         | 3(3.4)                       | 0                  | 3(12)             |         |
| Left lateral sectionectomy | 25(28.1)                 | 24(37.5)           | 1(4)              | -0.0001c|
| Wedge resection         | 44(49.4)                     | 33(51.6)           | 11(44)            |         |
| Left lateral sectionectomy + wedge resection | 1(1.1)               | 1(1.6)             | 0                 |         |
| Segmentectomy + wedge resection | 1(1.1)               | 0                  | 1(4)              |         |
| Difficult Index Score High [n(%)] |                                |                    |                   |         |
|                         | 12(13.5)                      | 7(10.9)            | 5(20)             | 0.306b  |

**Footnotes:** ASA American Society of Anesthesiology, AST enzyme aspartate aminotransferase, ALT enzyme alanine aminotransferase, BMI body mass index, IPNB Intraductal papillary neoplasm, SD standard deviation.

Assessed in 25 patients with colorectal, breast or esophagus liver metastasis.

*Mann-Whitney U test; 'Fisher's Exact test; 'Chi square test.
Table 3. Cost analysis (estimated in euros) for patients operated on by da Vinci Si (n=64) or da Vinci Xi (n=25) for minor hepatic resections.

|                          | Total study population (n=89) | da Vinci Si (n=64) | da Vinci Xi (n=25) | p value | Adjusted p value OR or MD (95%CI) |
|--------------------------|------------------------------|--------------------|--------------------|---------|----------------------------------|
| Blood transfusion [n (%)]| 3(3.5)                       | 2(3.3)             | 1(4)               | 1       | 0.996                            |
| Time to flatus (days) [median (range)] | 3(1-5)                   | 3(1-5)             | 2.5(1-3)           | 0.011   | 0.015 MD: 0.75 (0.15-1.36)       |
| ICU stay (days) [median (range)] | 1(0-9)                     | 1(0-9)             | 0(0-2)             | >0.0001 | 0.086                            |
| Hospital stay (days) [median (range)] | 5(2-22)                | 5(2-22)            | 5(2-13)            | 0.586   | 0.613                            |
| R1 surgical margins [n (%)] | 9(10.1)                    | 7(10.9)            | 2(8)               | 1       | 0.992                            |
| Postoperative complications [n (%)] | 15(16.9)               | 10(15.6)           | 5(20)              | 0.754   | 0.405                            |
| Type of complication [n (%)] |                             |                    |                    |         |                                  |
| • Prolonged pain          | 5(5.6)                      | 4(6.3)             | 1(4)               | 1       | 0.814                            |
| • Hemorrhage              | 3(3.4)                      | 3(4.7)             | 0                  | 0.556   | 0.997                            |
| • Ascites                 | 3(3.4)                      | 3(4.7)             | 0                  | 0.556   | 0.998                            |
| • Pulmonary infection     | 3(3.4)                      | 2(3.1)             | 1(4)               | 1       | 0.999                            |
| • Surgical site infection | 7(7.9)                      | 4(6.3)             | 3(12)              | 0.396   | 0.104                            |
| Severe morbidity (Dindo-Clavien >III) [n (%)] | 5(5.6)                | 4(6.3)             | 1(4)               | 1       | 0.496                            |
| Reoperation [n (%)]       | 1(1.1)                      | 1(1.6)             | 0                  | 1       | 1                                |
| 90-day post-operative mortality [n (%)] | 0                            | 0                  | 0                  | NA      | NA                               |
| Analgesic use (days) [median (range)] | 16(7-30)               | 15.5(7-30)         | 19(13-30)          | 0.092   | 0.212                            |

Footnotes: SD standard deviation; MD mean difference; OR odds ratio.

Discussion

The present study shows that minor hepatectomies can be performed with the da Vinci Xi surgical system by using a lower number of ports, with the consequent advantages of a shorter total incisional length for the patient compared to the Si system. Moreover, patients operated on by the Xi system showed a shorter time to flatus, probably reflecting a more rapid recovery, which...
however cannot be detected on the overall hospital stay and complication rate, which were not different between the two groups.

The main technical advantage of the shift from the Si to the Xi system can be seen in the use of less laparoscopic assistant ports and laparoscopic devices. Indeed, with the Si surgical system, several procedural steps of the minor hepatectomy are carried out using laparoscopic energy devices, such as the Harmonic Scalpel, LigaSure, mechanical staplers, and ultrasonic dissector (Cavitron), operated by the assistant surgeon (9, 13, 14, 36). On the contrary, the Xi surgical system is associated with a new generation of robotic vessels sealer that, in combination with all other Endowrist devices and the robotic Maryland forceps, allows to divide the majority of the hepatic parenchyma and to coagulate small vessel branches. This new robotic device is characterized by an enhanced access and control due to a 30% slimmer jaw profile for more precise dissection, a grasp with a textured surface to secure tissue, and an approach to anatomy from the preferred angle by articulating the wrist. It allows to seal and cut vessels up to 7 mm in diameter and consents to reproduce the clamp crushing technique, considered as one of the most efficient parenchyma liver transection (37).

Practically, the entire procedure is performed by the first operating surgeon at the robotic Xi system console using all robotic working ports and devices under 3-D view, translating into a “less hybrid” technique compared to the Si system and previous robotic platforms, because the need of laparoscopic device during the hepatic transection is minimized. Another advantage of the Xi surgical system is that the robotic camera can be placed in any of the 8-mm robotic ports; this can also be changed during the procedure in the need to have the third robotic working arm on the right side or on the left side of the operative field.

In the present study, these technical advantages appeared to have an impact on the instrument/device related costs, which were lower when operating with the Xi than the Si system. However, no conclusion on the potential economic benefit of the Xi robotic platform can be ascertained from the present study because once taken into account confounders, no group difference was noted for total costs, operative room occupation costs, hospital stay costs, and instrument costs. Although previous studies suggested further advantages of the Xi system in term of operative time (23, 38, 39) with potential impact on improved efficacy and reduced costs, this was not observed in the present analyses and further investigations are needed to conclude about the cost-effectiveness of both robotic surgical systems.

On the patient’s perspective, the use of one laparoscopic assistant port instead of two and an 8-mm port instead of 12-mm one for the robotic camera, translates to a shorter total incisional length, which is an important determinant of postoperative pain, analgesic need, recovery time, and finally cosmetic results (40, 41). However, in this first report, patients operated on by the da Vinci Xi system only showed a shorter time to flatus, without differences in postoperative complication rate, analgesic use, need of re-operation, and hospital stay. It can be hypothesized that the use of Xi system may be associated with improved outcomes and faster recovery related to a reduced abdominal wall stress and pain compared to the Si System. However, this needs to be investigated in further studies, ideally randomized trials in which the role of confounders is minimized and the internal validity is maximized.

The present study has several limitations, mainly related to the retrospective design and small simple size. Selection and reporting bias cannot be excluded. Despite the statistical adjustments made, residual confounding factors must be considered while interpreting the present results. Moreover, findings cannot be generalized without caution, since all procedures were performed by experienced surgeons having completed their learning curve and operating in referral centers. Indeed, evidence suggests that to ensure safety and efficacy of robotic liver procedures, the surgical team must be optimally trained and experienced (38, 42). Further studies are awaited to detect potentially relevant differences between the Xi and Si robotic surgical systems, which may not have been identified in the present study due to the small sample size, and to confirm the present preliminary report. It would be interesting to assess docking time separately to the procedure time and the cost-effectiveness of Xi robotic system compared to laparoscopy. Indeed, laparoscopy is nowadays considered as the gold standard approach for selected minor hepatectomy (43, 44). Particularly, previous studies on
the use of robotic surgery for left lateral sectionectomy showed that it yields similar or slightly inferior clinical outcomes than laparoscopy, but with increased costs and time (45-48). However, these data should be updated after the widespread implementation of the da Vinci Xi surgical system, which has the technical characteristics to definitively overcome laparoscopic drawbacks and reduce robotic surgery inconveniences.

Conclusion

Within the limitations of the present study, which is in our knowledge the first one to compare two generations of robotic surgical systems for minor hepatectomies, the da Vinci Xi system represents a technological advancement with potential clinical relevance. However, further studies are needed to clearly detect the clinical impact of the use of this new generation robotic platform in liver surgery.

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List of abbreviation: ICU: intensive care unit.

Ethical approval and consent to participate. This is retrospective study dealing exclusively with anonymous clinical record data routinely collected in health databases. This research complies with the MR004 regulation; it was declared to the National Commission for Data Protection and Liberties (CNIL: 2210699). All personal data were collected after informing the involved patients and were treated in conformity to the ethical standards of the Helsinki Declaration.

Availability of data and materials. Upon reasonable requested to the corresponding author.

Competing interests. Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

Authors’ contributions. NdeA, DS and RM participated in patient treatments, study design, and manuscript drafting. NdeA, RM, NM, NB and GB contributed to the data collection and data analysis. MA, RI, HH, GS and AL contributed to data interpretations and manuscript critical revisions. All authors read and approved the final version of the manuscript.

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