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LETTER TO THE EDITOR

Use of a new integrated table motion for the da Vinci Xi in colorectal surgery

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Dear Editor:

Integrated Table Motion (ITM) for the da Vinci Xi surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) is a new feature comprising a unique operating table by Trumpf Medical Systems that communicates wirelessly with the da Vinci Xi. The ITM feature allows surgical staff to reposition the patient without undocking the robot and without removing instruments from inside the abdomen.

The da Vinci Xi surgical system and the TruSystem 7000dV operating table (TS7000dV, TRUMPF Medizin Systeme GmbH & Co. KG, Saalfeld, Germany) have been specifically developed to address some technical limitations of the da Vinci Si surgical system, and to improve multiquadrant robotic surgery. An important drawback during robotic procedures with the previous da Vinci Si system is the inability to move the table position with the robotic arms docked. This problem may be particularly amplified in multiquadrant operations, such as colorectal surgery, in which the patient and the robot itself need to be rearranged several times to optimally achieve different surgical targets or provide patient relief. Herein, we present the first study on human use of this device in colorectal surgery. The purpose of this study was to evaluate the efficacy, feasibility, and safety of ITM for the da Vinci Xi system in performing robotic colorectal resections.

Between May and October 2015, the first human use of ITM was carried out in a post-market study in the EU in which 40 cases from different specialties (general surgery, urology, or gynecology) were prospectively enrolled. The Ethics Committee of our institution approved this study. Patients who planned to undergo minimally invasive surgery within the specialties of general surgery, urology, or gynecology with the commercially available da Vinci Xi surgical system and who were eligible based on the inclusion and exclusion criteria of this study were offered enrolment. Study-specific informed consent was obtained in writing from each patient before any procedure specific to the clinical investigation was performed.

Inclusion criteria were as follows: body mass index ≤45 kg/m^2; age 18 years or older; suitable for minimally invasive surgery; undergoing a surgical procedure in urology, gynecology, or general surgery; ability to tolerate the Trendelenburg position; willingness to participate as demonstrated by giving written informed consent. Exclusion criteria were as follows: American Society of Anesthesiologists (ASA) IV patients; pregnancy; lack of cooperation due to psychological or severe systemic illness; comorbid medical conditions contraindicating general anesthesia or standard surgical approaches; vulnerable population (such as prisoners, mentally disabled); anatomy unsuitable for endoscopic visualization or minimally invasive surgery; extensive previous abdominal surgery; patient not

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compatible with the Trumpf TS7000dV operating table due to weight >1000 lbs, allergy to table material, stature not fitting on table, inability to be positioned for surgery, or inability to get low enough for robotic docking.

The colorectal study group comprised 10 patients. Preoperative imaging was achieved by colonoscopy, with biopsies taken of colorectal lesions; patients also underwent computed tomography scanning, magnetic resonance imaging, and other specific examinations when necessary. Variables examined included patient demographics and characteristics such as age, height, weight, sex, ASA score, comorbidities, and previous abdominal surgery. We collected data regarding the patient position on the table, surgical approach, targeting, procedure operative times, distinguishing operating room enter/exit time, anesthesia start/stop time, operative start/stop time, and robot dock/undock time.

Primary end-points were ITM efficacy, safety, and feasibility. We evaluated efficacy and feasibility by assessing the number of ITM moves made per case, duration of each table motion, table position attained, reasons for moving the table, and the state of the instruments and endoscope during table motion (inserted or removed). We evaluated the safety of ITM by analyzing patient vital data (pre- and post-operative mean blood pressure and heart rate), estimated blood loss, urine volume, total administered fluid, port-site condition, intra- and post-operative complications, adverse events related to the use of ITM (incidence of tissue/nerve/organ injuries), and discharge date. Variables of interest were analyzed retrospectively after Institutional Review Board approval. Sample characteristics were assessed using descriptive statistics. Continuous variables were expressed as the mean, median, and range, whereas categorical variables were expressed as counts and percentages. Analyses were done using the statistical package SPSS®, version 17 (SPSS Inc., Chicago, IL, USA).

During the study period, seven patients underwent ARR with TME, two patients underwent right colectomy (RC), and one patient underwent sigmoidectomy. Mean operating room enter/exit time was 422 min (median 415 min, range 285–670 min), mean anesthesia start/stop time was 402.9 min (median 397.5 min, range 280–655 min), and mean robotic time was 237 min (median 227 min, range 128–450 min). We obtained targeting success in all cases. The mean number of ITM moves was 3.3 (median 3, range 2–6), resulting in 33 instances of table moves in 10 procedures. The mean duration of each table motion was 99 s (median 77 s, range 12–380 s). The desired table position was attained in all cases. The reason for moving the table was to gain internal exposure in 30 cases (91 %), to change target in two cases (6 %), and to improve external access and allow tumor removal in one case (3 %). The endoscope was left inserted during 31 of the 33 table movements (94 %), and the instruments were left inserted during 28 of the 33 table movements (84.8 %). The ITM duration was less than 2 min per move in 25 of 33 of moves (75.8 %). During ARR and sigmoidectomy, the mean number of ITM moves was 3.37, resulting in 27 instances of table moves; during RC, the mean number of ITM moves was three, resulting in six instances of table moves. The mean duration of each table motion was 108 s during ARR and sigmoidectomy, compared with 59 s during RC. The most common reason for moving the table during ARR and sigmoidectomy was to gain external exposure; the reason for moving the table during RC was to gain external exposure in all cases. Mean estimated blood loss was 82 ml (median 25 ml, range 10–500 ml), mean urine volume was 748 ml (median 640 ml, range 300–1500 ml), and mean total volume of administered fluid was 3550 ml (median 3500 ml, range 2000–6000 ml). The mean pre- and post-operative blood pressure was 134/72 mmHg (median 130 mmHg, range 105–165 mmHg) and 128/70 mmHg (median 130 mmHg, range 100–160 mmHg) respectively. The mean pre- and post-operative heart rate was 61.8 bpm (median 57.5 bpm, range 45–80 bpm) and 57.9 bpm (median 57.5 bpm, range 40–84 bpm), respectively. The mean hospital stay was 12.4 days (median 6 days, range 5–60 days). The port site condition was undamaged in all cases. No external instrument collisions or other problems related to the operating table were noted. There were no ITM-related intra- and post-operative complications or need to convert to laparoscopy or laparotomy. There were no ITM safety-related observations and no adverse events.

The da Vinci Xi is the latest release product of Intuitive Surgical systems; this product heralds an important change and innovation in form and functionality compared with the previous version. The new overhead architecture combines the functionality of a boom-mounted system with the flexibility of a mobile platform. Although the maneuverability of this new generation of the da Vinci system seems superior to its predecessor, the fixed patient position still limits the working space in some border areas. Undocking, instrument extraction, and cart repositioning could remain necessary for better exposure or patient safety, similarly to the previous da Vinci Si; this may impede the flow of the operation.

ITM makes it possible to move the operating table without removing the instruments from inside the abdomen, which simplifies the work flow without struggle or taking time to undock/re-dock the platform. ITM allows surgeons to maximize all the advantages of the robotic method while reducing its specific drawbacks, enabling access to different parts of the anatomy in a faster manner during procedures that involve more than one target anatomy. In these situations, similarly to laparoscopy, the da Vinci Xi plus the new operating table give the potential to optimize gravity exposure and provide the quick access to different surgical objectives that is important in colorectal surgery. These can be accomplished robotically by regulating the Trendelenburg and lateral tilt of the ITM

without undocking the robotic platform. In the present study, most ITM movements during colorectal interventions took less than 2 min, permitting a fine regulation during all surgical phases that is not possible without its use. With increasing familiarity with this new device and having established its safety, we have tried to follow a standardized approach regarding table movements and reasons for ITM usage for both ARR and RC. For ARR, the patient was generally arranged in 10° Trendelenburg position and tilted to the right for inferior mesenteric vein exposure, then in 8° reverse Trendelenburg position for splenic flexure mobilization, then a 20° Trendelenburg position for the total mesorectal excision and pelvic phase. In cases of robotic RC, the bed was tilted 10° to the left for vascular pedicle ligation and right colon mobilization, and then a reverse Trendelenburg position was used for right flexure mobilization and performing tension-free intracorporeal ileocolic anastomosis. ITM provided stable patient repositions and powerful gravity traction under the surgeons' control, providing ideal surgical exposure in all phases of the intervention.

Another important consideration is that the TruSystem 7000dV could increase patient safety in extreme Trendelenburg positions. In our preliminary experience, some anesthesiologic parameters were considered as indirect signs of ITM safety. There were no important hemodynamic changes during the entire course of surgery, and pre- and post-operative blood pressure and heart rate were similar. ITM may contribute to patient relief during Trendelenburg surgery (not only from an hemodynamic point of view but also by preventing increased intraocular pressure, neurologic, or soft tissue injuries), minimizing use of extreme positions by starting with a less extreme patient position and changing to more extreme positions only when necessary. Moreover, it gives anesthesiologists the ability to precisely control patient positioning and display the table position to the entire surgical team (the degree of Trendelenburg and tilt are displayed on the remote, Vision System Cart monitor, and Surgeon Side Console monitor).

Limitations of the present pilot study are related to the small sample size, the heterogeneity of surgical procedures, and differences in the learning curve period of surgeon groups that preclude definitive conclusions about ITM clinical advantages in reduction of overall operative time. Nevertheless, further studies may demonstrate whether ITM could enable procedures (or part of procedures) to be done robotically that would otherwise be difficult, and whether ITM could improve operative efficiency by reducing surgical operative time. Cost analysis is also important in evaluation of these devices.

In conclusion, colorectal procedures require a broad operative field and several anatomical targets that span different abdominal quadrants. The advent of the da Vinci Xi and the new operating table that communicates wirelessly with the robotic platform can overcome the intrinsic limits of robotic surgery, while maintaining its specific advantages. This preliminary study demonstrated the feasibility of ITM in performing da Vinci Xi colorectal operations, which enabled patient repositioning without disrupting surgical workflow by allowing the surgeon to leave instruments in place and the endoscope docked to the patient. This is particularly important in the general surgery field to accomplish all surgical steps with optimal exposure due to robotic countertraction and gravity. ITM was safe, and no adverse events related to its use were reported. Moreover, patient safety is increased as it is possible to modify extreme positions to reach a good compromise between optimal visceral exposure and anesthesiologic risks.

Compliance with ethical standards The Ethics Committee of our institution approved this study.

Conflict of interest The authors declare that they have no conflicts of interest.