Techniques in Coloproctology (2019) 23:471–477
https://doi.org/10.1007/s10151-019-01992-1

MULTIMEDIA ARTICLE

Assessment of the Versius surgical robotic system for dual-field synchronous transanal total mesorectal excision (taTME) in a preclinical model: will tomorrow's surgical robots promise newfound options?

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Received: 19 March 2019 / Accepted: 15 April 2019 / Published online: 8 May 2019

Abstract

Background The aim of this study was to evaluate the feasibility of the Versius surgical robotic system for transanal total mesorectal excision (taTME) in a preclinical setting.

Methods Dry laboratory and cadaveric sessions were first conducted for three experienced colorectal surgeons in order to gain familiarity with the modular surgical system and the robotic workstation. After introduction, the system was configured to allow for synchronous, totally robotic taTME in a cadaver.

Results Using the modular robotic system, one surgeon performed the abdominal portion of the operation, including colonic mobilization and vascular pedicle ligation while simultaneously a second surgeon performed the transanal portion of the operation to the point of rendezvous at the peritoneal reflection, where the operation was completed cooperatively. The operation was successfully completed in 195 min demonstrating preclinical feasibility of this unique approach with an emerging robotic system.

Conclusions This is the first preclinical assessment of the Versius surgical robotic system for taTME. The ability to work simultaneously carries the theoretical advantage of reducing surgical time and thereby reducing overall operative costs. It may also allow surgeons to maintain focus on critical parts of the operation by halving the fatigue associated with long, complex cases such as taTME.

Keywords Cooperative robotic surgery · Two-field surgery · taTME · Cecil approach · Synchronous surgery · Versius · Modular surgical robotics

Introduction

Transanal total mesorectal excision (taTME) is a disruptive technology in the approach to rectal cancer surgery that has evolved swiftly since the time of its inception in 2009 [1–4]. The decade-long evolution of taTME has been matched by the rapid development of new surgical platforms designed to provide unmet needs of approach and access [5–9].

Today, the majority of experts performing taTME routinely do so utilizing a two-team (dual-field) approach, most commonly via laparoscopic transabdominal access coupled with transanal access [10]. From a practical standpoint, there is a limit to the degree of synchronous surgery (ie, Cecil approach) and the length of total operative time for which synchronicity can be applied. This is because the surgical field becomes crowded by theatre personnel, equipment, and

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10151-019-01992-1) contains supplementary material, which is available to authorized users.

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surgeons, making it difficult to share operative fields. It is also because position changes (such as those required for splenic flexure release) pose a hindrance to the length of time for which simultaneous abdominal and transanal surgery can be realistically performed by dual bedside surgical teams. Because of this, the totality of true synchronous operating time with the two-team approach is only moderately reduced—thereby resulting in a small decrease in overall surgical case time and utilization-dependent operative costs [11–13].

Robotic taTME has been shown to be technically feasible [14, 15], and such an approach may someday provide a solution to the *Achilles' heel* of rectal cancer surgery [16, 17]. While totally robotic taTME has also been described by M. Gomez et al. using the da Vinci *Si* Surgical System [18], cart re-docking is required and the procedure cannot be completed in synchronicity.

Simultaneous two-field robotic taTME utilizing the *Xi* platform has been trialed by our center [19], however, there are critical limitations that prohibit its practical use—most notably, the limitation of four robotic instrument arms with the limit of a singular robotic camera.

The Versius surgical robotic system (CMR Surgical, Inc. Cambridge, UK) is an emerging, next-generation robotic system with a modular design that provides configuration options suitable to the surgeon and the case. With dual-consoles, two surgeons are able to operate along different anatomic fields simultaneously and independently; this could potentially be applied to taTME surgery in humans (Fig. 1a, b). In a cadaveric model, the feasibility of the modular-designed Versius robotic system to perform dual-field synchronous, totally robotic taTME was assessed. The aim of this study was to demonstrate proof-of-concept in using a modular robotic system to complete such an operation with two surgeons operating in synchronicity.

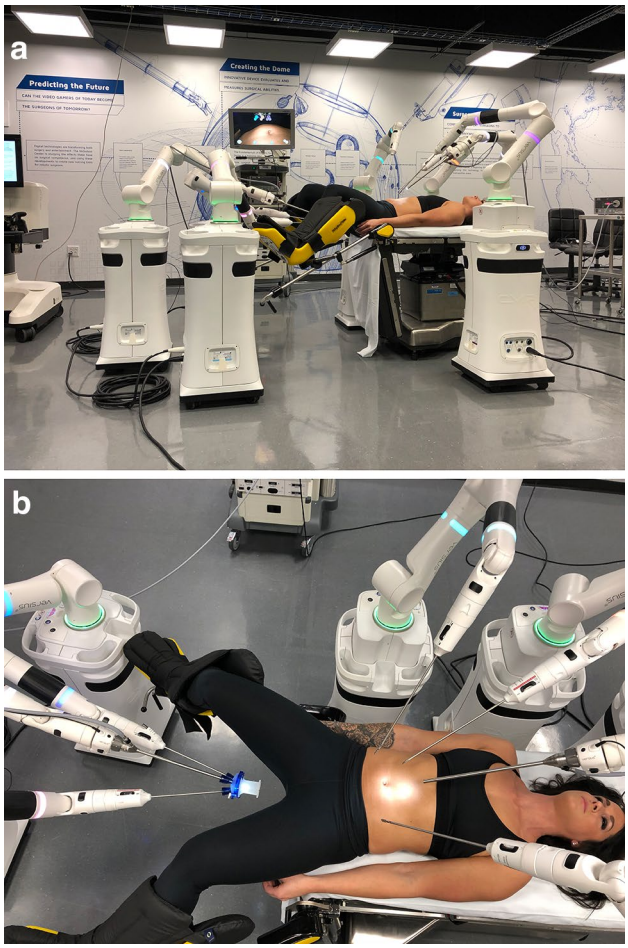

Fig. 1 **a**, **b** Shown is the modular Versius robotic system in a configuration suitable for synchronous dual-field taTME. Here illustrated for a human, this was the arrangement used during preclinical cadaveric experimentation

Methods

Three fellowship-trained colorectal surgeons with extensive laparoscopic and da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) experience underwent training on the Versius Robotic Surgical System (CMR Surgical, Inc., Cambridge, UK). The two robotic systems (Versius and da Vinci) are similar in that the surgeon may be seated at a console removed from the patient's bedside, however the Versius system differs from da Vinci in that the robotic arms are modular, which adds arm positioning flexibility in configuration. A comparison of the two systems is delineated in Table 1.

The surgeons were also trained to operate the unique left and right-hand control boxes, which mirror the general design of video gaming controllers (Fig. 2). This is a notable departure from da Vinci console design, because the Versius system does not require foot pedal control—i.e., all robotic device control has been placed onboard handheld control units.

After a dry lab introduction of the Versius system, each surgeon was provided the opportunity to advance their training in a cadaveric model. Each surgeon performed either splenic flexure mobilization, sigmoid colectomy, or taTME. The objective was to gain familiarity with the robotic system's operation and performance.

A cadaveric model was chosen to assess the feasibility of two-field robotic surgery for taTME. A fresh-frozen human cadaver was thawed and prepared on an operating table at a surgical site training center (Global Robotics Institute, Nicholson Center, Celebration, FL, USA). Abdominal access was achieved via 5 mm laparoscopic trocars and, simultaneously, transanal access was established via a TAMIS port (GelPOINT Path, Transanal Access Platform, Applied

Table 1 Similarities and differences between da Vinci *Xi* and Versius robotic surgical platforms

	da Vinci *Xi*	Versius
Manufacturer	Intuitive surgical	CMR surgical
Country of origin	United States	United Kingdom
FDA status	Approved in USA	Pending in USA
System cost	$2 million	Undisclosed
Console/workstation	Remote (closed)	Remote (open)
Number of consoles	2 possible	2 possible
Arm configuration	Single cart	Modular
3D viewing	Viewfinder	Passive 3D glasses
Number of arms	4 max	7 (experimental only)
Effector arm diameter	8 mm	5 mm
Ability to employ trocars	No	Yes
Foot pedal control	Yes	No
Gravity compensation	Yes	Yes
Ability to operate in 2 fields	No	Yes (experimental)
Effector arm lifespan	10	13 (projected)
Simulator available	Yes	Yes

Medical, Inc.). Insufflation was established in both fields, with conventional CO_2 insufflation for the abdomen. To assure pneumatic stability for the transanal portion, a valveless 8 mm trocar adapted to the TAMIS port and connected to a high flow, dynamic insufflation system (AirSEAL, ConMed, Inc., Utica, NY) was utilized.

The nomenclature suggested by the manufacturer is used herein. The robotic effector arm has thus been termed an *instrument bedside unit* (BSU), while the robotic camera has been defined as the *visualization* BSU. Three instrument BSUs and one visualization BSU were configured along the cadaveric torso while two instrument BSUs and an additional visualization BSU were configured transanally; each field (transanal and abdominal) configured with their own, surgeon controlled robotic camera. In total, seven BSUs (operated by two surgeons stationed at separate, open-design consoles) were arranged to conduct this cadaveric study (Fig. 3).

Three BSUs were configured in an 'arm-over-arm' position transanally with the 5 mm instrument effectors delivered directly through the TAMIS port cannulas, with one instrument BSU delivered through the valveless (AirSEAL®) trocar equidistantly. For the abdominal configuration, three instrument BSUs were positioned to the right of the torso and delivered along the right lateral abdomen via three 5 mm standard laparoscopic trocars (Fig. 4). Meanwhile, a fourth BSU was positioned to the left of the torso, and the robotic instrument effector was used to access the abdomen via an additional 5 mm trocar. An optional fifth abdominal trocar was used for operation by a bedside assistant surgeon; this was rarely required during the procedure, and only as need for occasional organ retraction and/or intermittent smoke evacuation via laparoscopic suctioning.

It should be noted that the applied configuration and surgical approach is currently beyond the scope intended by the manufacturer. IRB review was not required for this study as it did not involve human subjects. Cadaveric handling and preparation was performed in accordance to the protocols of the host institution.

Results

Three surgeons participated and successfully completed the taTME operation. The abdominal surgeon and the transanal surgeons worked separately at times, such as during initiation of taTME with rectotomy and splenic flexure release (Fig. 5). At other times, the surgeons worked cooperatively, for instance at the point of rendezvous (Fig. 6). As necessary, a third surgeon was available to assist with retraction or smoke evacuation through an abdominal 5 mm laparoscopic port, although this was seldom required. There was no assistant for the robotic transanal portion of the operation.

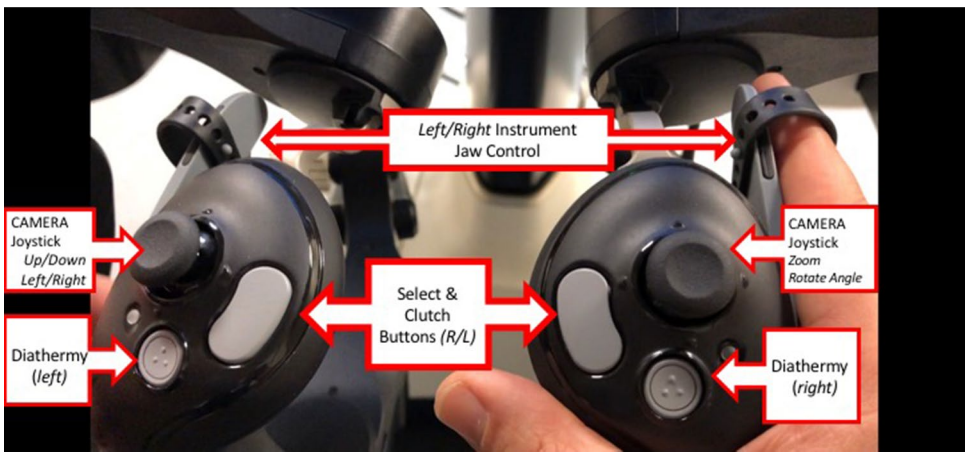

Fig. 2 Versius surgeon gravity compensating control units for left and right hands is illustrated. The system does not have foot pedal controls, as operation of the robot is solely via onboard 'gaming style' devices

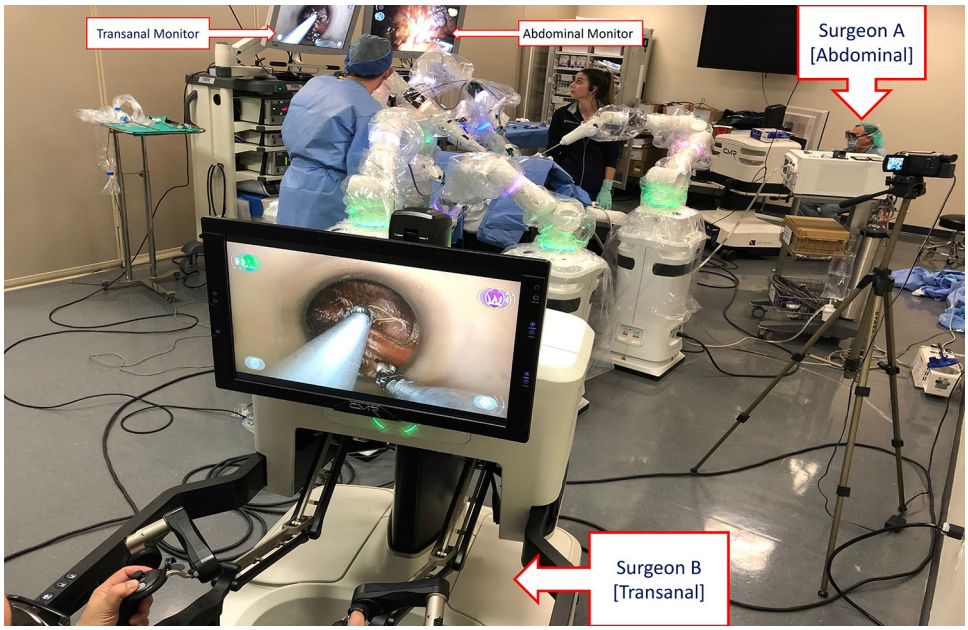

Fig. 3 Physical arrangement of the Versius robotic surgical system during synchronous dual-field cadaveric taTME. Note the position of the two open-console surgeons and the dual monitors (one for each field)

Fig. 4 Robotic dual-field synchronous taTME in a cadaveric torso. A modular design provides inherent flexibility in configuration. Here, four BSUs were used for the abdominal portion of the totally robotic taTME, while three BSUs have been configured for the transanal portion of the operation, delivered via a TAMIS port (not visible)

The examined cadaveric rectum was removed intact with only minor defects to the mesenteric envelope observed (Quirke Grade II). Surgeon console time was recorded as 150 min and encompassed full left colonic mobilization with high-tie pedicle ligation, splenic flexure release, the transanal portion of the taTME operation, rendezvous, and finally specimen extraction. Conduit reconstruction was not performed. An additional ~ 45 min of non-console time was allocated to BSU positioning and configuration. This likely required substantial time and effort due to lack of precedent for two-field robotic taTME using the Versius platform. Total operative time thus measured 195 min. The approach is detailed in the supplemental video content available online.

Fig. 5 Dual-field robotic surgery. In this instance, the two console surgeons operate simultaneously in separate fields and separate anatomic compartments. In the abdominal cavity, the splenic flexure is released, while from the transanal approach, rectotomy is performed. Such an approach could theoretically reduce overall operative time

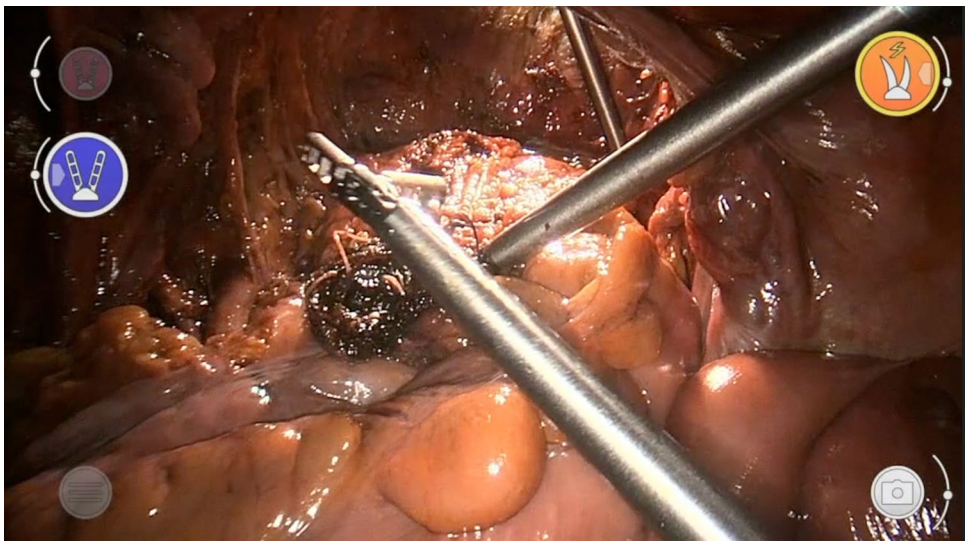

Fig. 6 Upon rendezvous, the pelvic and abdominal cavities become a single operative field. Rather than operating synchronously and separately, the dual robotic surgeons now operate cooperatively to complete the operation. This is essentially a totally robotic Cecil approach

Discussion

In this initial, preclinical report on the use of the Versius robotic system for colorectal applications, taTME was successfully performed capitalizing on the ability to carry out surgery in two surgical fields simultaneously. It is a conceptual application of the emerging, not yet Food and Drug Administration (FDA)-approved device that awaits clinical validation. The aim of this study was to explore the potential of this system, and perhaps other modular-based medical robotic systems, to synchronously perform surgery in more than one field.

There is unquestionable benefit to surgical synchronicity. Two-field surgery, when case complexity warrants such an approach, can add value by reducing anesthetic time and overall operative time. Effective examples of synchronicity in surgery are not limited to colorectal or even to minimally invasive operations, and include vein harvest during coronary artery bypass grafting, organ transplantation, two-field esophagectomy for cancer of the distal esophagus [20], and abdominoperineal resection [21]. The Cecil approach for taTME is perhaps the latest example of synchronicity which not only capitalizes on the ability to work in two body cavities simultaneously, but also results in an important, 'cooperative point' when the abdominal and pelvic cavity become one—at the critical point of rendezvous. Advantages of cooperative surgery include decreased operative time, decreased surgeon fatigue and stress, and, potentially, improved clinical outcomes. Furthermore, since robotics minimizes the role and need for an assistant, the 'two-team' can be reduced in personnel to the two console surgeons alone; with perhaps only an experienced scrub nurse or bedside surgical

Table 2 Potential advantages of synchronous dual-field robotic surgery for complex operations

1.	Reduced overall surgical and anesthetic time
2.	Improved operative efficiency
3.	Diminished overall operating room cost
4.	Decreased surgeon workload, stress, and fatigue
5.	Provided ability to operate cooperatively
6.	Decreased need for human resources/OR personnel

assistant. This and other potential advantages of dual-field robotic surgery are illustrated in Table 2.

In order to solve the problem of robotics in relation to cost, two options can be considered. First, a reduction in the direct, per-case cost of robotic platform use is essential, but has been difficult to achieve in the current healthcare market [22]. Second, a reduction in the amount of operative time required with robotics by improving (a) operational speed (the surgeon may be able to operate *safely* faster through AI-based assistance) and/or by (b) cooperative approaches that, for complex surgery, allows two surgeons or more to operate in > 1 surgical field to complete the operation.

While two-field surgery for taTME may be currently only theoretical, in this preclinical assessment, such an approach appeared to be feasible. Perhaps the coming age of modular and configurable robotic arms will challenge surgeons to consider options which had previously been simply unfathomable. It is through this kind of rethink that the surgical robots of tomorrow will evolve.

Conclusions

This is the first preclinical assessment of the Versius surgical robotic system for taTME. Operating in two fields represents an altogether new option for robotics. The ability to work simultaneously carries the theoretical advantage of reducing surgical time and thereby reducing overall operative costs. It may also allow surgeons to maintain focus on critical parts of the operation by halving the fatigue associated with long, complex cases such as taTME.

Funding CMR Surgical provided the funding and resources necessary to conduct this study.

Compliance with ethical standards

Disclosures Dr. S. Atallah reports consultancy (such as consulting fees, honoraria) from Medtronic, Applied Medical, ConMed, Inc, and Medrobotics. Dr. A.G.F. Melani receives remuneration (payment for services not otherwise identified as salary such as consulting fees, honoraria) from Medtronic, Ethicon, Intuitive Surgical, and Verb Surgical though he has no direct conflicts of interest with content discussed in this manuscript. Dr. E. Parra-Davila receives remuneration (payment for services not otherwise identified as salary such as consulting fees, honoraria) from Medtronic, Ethicon, Intuitive Surgical, and Verb Surgical though he has no direct conflicts of interest with content discussed in this manuscript.

Ethical approval This research was performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained in accordance with the standards set forth by hospital regulations.

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