

Analyzing the Potential Benefits of a Novel Multifunctional Laparoscopic Surgical Device Prototype

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Abstract

Background: Excessive laparoscopic instrument exchanges contribute to operative inefficiency, workflow disruption, surgeon fatigue, and increased operating room (OR) costs during minimally invasive surgery (MIS). Multifunctional laparoscopic technologies may help address these limitations by reducing instrument exchanges and improving procedural efficiency.

Methods: A narrative review of the literature was conducted using PubMed, Google Scholar, and surgical device registries through February 2025 to evaluate evidence related to operative time, instrument exchanges, surgeon ergonomics, workflow disruptions, complication risk, and OR costs in laparoscopic surgery. A novel multifunctional laparoscopic prototype capable of automated intracorporeal tip switching was analyzed. Simulated workflow modeling was performed using retrospective procedural data from a high-volume MIS practice to estimate the potential impact of the device on instrument exchanges, operative time, OR costs, and workflow efficiency across several common laparoscopic procedures.

Results: Published studies consistently demonstrated associations between prolonged operative duration, frequent instrument exchanges, surgeon fatigue, workflow interruptions, and increased complication rates. Simulation modeling suggested that using a multifunctional prototype could reduce external instrument exchanges, depending on procedure complexity. The greatest modeled benefits were observed in longer and more technically complex procedures.

Conclusion: A multifunctional laparoscopic device with automated intracorporeal tool switching (Symphera) may improve operative workflow and reduce inefficiencies associated with conventional laparoscopic instrument exchanges. While early simulation

and preclinical data are promising, these findings are based on model projections and narrative synthesis of the literature. Prospective clinical studies are required to validate the safety, clinical effectiveness, ergonomic impact, and economic value of this investigational technology before widespread adoption can be considered.

Keywords: Surgical innovation, New technology, Laparoscopy, Multifunctional device, Instrument exchanges

INTRODUCTION

Minimally invasive surgery (MIS) has revolutionized surgical practice, reducing postoperative morbidity, shortening hospital stays, and improving patient recovery times. Despite these advantages, MIS procedures face persistent challenges, including operational inefficiencies, financial constraints, surgeon fatigue, and workflow disruptions that limit their full potential. The increasing complexity of surgical interventions, coupled with rising healthcare costs, demands a data-driven approach to optimizing efficiency and resource utilization in the operating room (OR). This article reviews and synthesizes studies on key aspects of laparoscopic surgery, including operative time and surgical efficiency, cost analysis and economic impact, safety considerations, and resource utilization. It draws on various studies to address challenges in laparoscopic instrument use, ergonomics, surgeon fatigue, workflow disruptions, infection control, and complication prevention. This detailed review reveals the association between increased instrument exchanges, prolonged operative time, and increased complication rates, and the growing need for OR workflow optimization. A novel multifunctional laparoscopic surgical device and its potential clinical and economic benefits in MIS are analyzed, and specific case examples are highlighted. The goal is to describe this new technology and offer practical insights into this device to serve as a reference for upcoming clinical research, potential Food and Drug Administration (FDA) approval, and clinical use.

METHODS

In this narrative review, an initial search was performed using PubMed,

Google Scholar, and major device registries to identify current or past surgical instruments with multifunctional features. Key themes and developments in multifunctional laparoscopic technologies were identified using this targeted search. Prototype information and figures were provided by Symphera. The clinical concepts potentially impacted by this novel prototype were identified as: prolonged operative time and complications; the cost of OR time; the evolution of MIS and the cost of new technologies; surgeon fatigue and ergonomics; and laparoscopic instrument exchanges. Based on this inclusion rationale, a medical literature review was conducted in PubMed and Google Scholar, with an end date of February 2025. Using data extrapolated from this review and the tabulated clinical data, a simulation was performed to assess how this device may affect several commonly performed laparoscopic procedures.

RESULTS

Efficiency maintenance in a constantly evolving field

The field of MIS has transformed surgical practice over the past several decades, providing a less traumatic alternative to open procedures with fewer postoperative complications and faster recovery times, resulting in significant cost savings for healthcare systems. Despite these advancements, significant challenges persist. Prolonged operative times, intraoperative inefficiencies, rising equipment costs, and surgeon fatigue all impact the overall effectiveness of MIS. Studies indicate that inefficiencies in OR workflow can increase operative time by up to 20%, leading to higher costs.¹ Moreover, the financial burden of advanced surgical technologies, particularly robotic platforms, has

raised concerns about cost-effectiveness and accessibility.²

Minimally invasive surgery surgeons routinely expand the use of standard laparoscopic instruments to perform a variety of distinct functions in addition to their primary function. In 2002, Mehta *et al.*³ analyzed the dynamics of laparoscopic instrument maneuvers and exchanges across 29 surgeries, including fundoplication, cholecystectomy, appendectomy, adrenalectomy, and nephrectomy. The curved dissector, atraumatic grasper, and cautery scissors were the most multifunctional instruments on a standard laparoscopic tray, as each was able to perform five distinct maneuvers. From this research came the realization that surgeons often use an inferior instrument to accomplish a task, avoiding an additional instrument exchange. For example, their data showed that the ultrasonic shears and the right-angle dissector were both used to retract, grasp, and dissect. The suction/irrigator was also used for retraction and blunt dissection. Similarly, suturing and suture tying were sometimes performed with the atraumatic grasper, curved dissector, and right-angle dissector. This highlights the surgeon's willingness to use an instrument for a purpose not intended by its designers if the instrument is adequate for the task, thereby maintaining surgical efficiency and avoiding multiple instrument exchanges.

Enhancements to current laparoscopic tools include wristed instruments that increase surgeon dexterity.⁴ Prototypes of automated tools that eliminate the need to remove the tool shaft from the patient's body have also been developed, though they have never made it to market.^{5,6} While these adjuncts have been widely implemented in robotic surgery, they have yet to gain significant traction in conventional laparoscopy and lack multi-tool or exchangeable tips.

Bipolar energy devices combine dissection, coagulation, and sealing functions in a single instrument, eliminating the need for frequent tool changes. A 2005 study showed that using integrated instruments can reduce operative time by 18%.⁷

There have been several attempts to create a next-generation multifunctional laparoscopic instrument, though none have been widely adopted. In 2005, Frecker *et al.*⁷ designed three multifunctional laparoscopic scissor-grasper prototypes: a combined scissors-grasper, an articulating scissors-grasper, and a compliant mechanism scissors-grasper. These were multifunctional single-tip devices that did not interchange. These were tested in a laparoscopic simulator, which showed that instrument switching was reduced by 46% compared to standard instruments and that procedural time improved by 18%. Despite these promising results, the prototypes did not perform as precisely or reliably as single-function laparoscopic tools and never reached production.

In 2009, Miller *et al.*⁸ explored how artificial intelligence (AI)-powered modular surgical instruments may reduce operative time and patient risk by eliminating unnecessary instrument exchanges. Using video recorded during laparoscopic cholecystectomy and laparoscopic Nissen fundoplication procedures, they created a prototype of a multifunctional laparoscopic tool that used a small direct-current motor to interchange six different instrument tips, with a tool-change time of approximately 11–13 s. Using this model in a laparoscopic trainer, they estimated that time savings for the procedures ranged from 2.5 to over 32 minutes. They concluded that, on average, total surgery time could be reduced by almost 17% with the laparoscopic multifunction tool.

The relationship between prolonged operative time and complications

Prolonged surgeries have been associated with a 4% to 14% increase in postoperative complications. Recently, Clapp *et al.*⁹ conducted a retrospective analysis of bariatric surgery outcomes from the MBSAQIP database to examine the association between operative time and outcomes. The median operative time for sleeve gastrectomy was 68 minutes, and 113 minutes for Roux-en-Y gastric bypass. They concluded that pro-

longed operative times were associated with higher complication rates, including infections, readmissions, reoperations, and longer hospital stays, though these findings were only correlational. Specifically, procedures exceeding 180 minutes had a 35% higher risk of complications compared to those completed in under 120 minutes ($p < 0.01$). Similar trends have been observed in colorectal, gynecologic, and urologic surgery.

A meta-analysis of 66 studies by Cheng *et al.*¹⁰ found that for every additional 30 minutes of operative time, the risk of complications increased by 14%. Procedures exceeding two hours nearly doubled the risk of complications. They also demonstrated that the likelihood of developing a complication increased with each 1-min, 10-min, 30-min, and 60-min increment in operative time (i.e., 1%, 4%, 14%, and 21%, respectively). These complications included: (i) increased intraoperative blood loss, (ii) increased postoperative venous thromboembolism, (iii) prolonged hospital stays, (iv) increased readmission rates, and (v) increased surgical site infections. There were 13%, 17%, and 37% increases in the likelihood of developing surgical site infection for every additional 15, 30, and 60 minutes of operative time, respectively. The findings were consistent across multiple surgical specialties, emphasizing the universal need to optimize operative efficiency. It was recommended that surgeons consider emerging technologies that reduce operative duration, and that future research explore innovative methods to improve intraoperative efficiency.

The financial burden of operating room time and resource utilization

A landmark study by Childers *et al.*¹¹ published in *JAMA Surgery* estimated that each minute of OR time costs approximately \$37 across multiple settings, with variations depending on hospital size, location, and surgical specialty. Two-thirds of OR costs were direct costs (e.g. surgical instruments). This study was based on data from over a decade ago, so the actual costs of today's ORs are likely much higher. For example, in 2022 Christou *et al.*¹² found that modern surgery accounted for nearly one-third of healthcare expenses, with a wide variation in OR costs ranging from \$7 to \$113 per minute.

Reducing the number of instruments opened per surgical procedure is a viable way to lower costs and improve efficiency in the OR. In 2019, Nast and Swords¹³ stated that instrument maintenance and sterilization cost approximately \$0.51–\$0.77 per instrument, and only 13–21.9% of the opened instruments are used. For example, after eliminating the excessive instruments in their inguinal hernia repair tray, they saved \$11,531 per year on this tray set alone. In 2025, Poder *et al.*¹⁴ demonstrated that making surgeons aware of the cost of their disposable instruments in real time can reduce unnecessary equipment use and yield cost savings of up to 24.5% per case.

The cost of minimally invasive surgery

While minimally invasive techniques enhance our ability to perform complex procedures with improved outcomes, they often entail higher upfront costs and greater infrastructure requirements.^{2,15,16} New technologies can be more expensive, and their clinical utility must be weighed against cost. Cost analyses often lack standardization, making cross-study comparisons difficult. For example, robotic systems enhance surgical precision, improve visualization, and shorten recovery times, but they also introduce higher capital investment requirements, annual maintenance costs, and increased cost per procedure.² The financial return on investment remains uncertain, as higher costs may not be fully offset by improved patient throughput or reduced complication rates. Laparoscopic surgery continues to offer a balance of cost and clinical benefits, showing lower overall per-case costs compared to robotic surgery, faster OR setup and turnaround times compared to robotic surgery, and significantly reduced hospital stay durations compared to open surgery.^{17–20}

Given these advantages, laparoscopy remains a financially sustainable approach for most general and specialty procedures. It is therefore reasonable to consider new laparoscopic tools that could enhance the surgeon's efficiency and assess their financial feasibility, similar to investing in robotic platforms.

The impact of surgeon fatigue and ergonomics on performance

Laparoscopic surgery involves unique ergonomic challenges compared to

open procedures, primarily due to awkward body positioning, limited range of motion, and reaching or extended postures. A study by van Veelen *et al.*²¹ used electromyography to measure muscle fatigue in surgeons using a prototype needle holder in a simulated laparoscopic environment, revealing high muscle activation in the shoulders and neck, which increased the risk of musculoskeletal disorders. Campetella *et al.*²² examined the physiological strain on MIS surgeons and found that fatigue-related errors increase after 4 hours of continuous operating, and 32% experienced significant hand and wrist fatigue, exacerbated by instrument handling.

Beyond physical strain, cognitive fatigue impairs reaction time, decision-making, and precision, particularly during long and complex surgeries. Sharma *et al.*²³ assessed device-related issues, team communication, situational awareness, and cognitive overload among laparoscopic surgeons, reporting that surgical accuracy declined by 17% after four hours of continuous operation, and device-related distractions occurred in 33% of surgeries, exacerbating mental fatigue. As such, there is great value in techniques and devices that limit the physiological toll and intraoperative distractions on laparoscopic surgeons.

Negative impact of excessive instrument exchanges on surgical performance

Extracorporeal (outside the body) instrument exchanges—the act of removing, retrieving, and replacing surgical tools during an operation—play a significant role in surgical ergonomics, workflow efficiency, and patient safety. Studies confirm that excessive instrument changes increase operative time, disrupt workflow, and contribute to fatigue-related errors. Geryane *et al.*²⁴ conducted a time-motion study of surgical trainees performing laparoscopic cholecystectomy, revealing that 17% of total OR time was lost due to unnecessary instrument exchanges. In the study, frequent switching between tools added an average of 12 minutes per procedure, and surgeons reported greater cognitive fatigue in cases with excessive instrument-handling demands. Similarly, in 2022, Tranter-Entwistle *et al.*²⁵ examined how technical difficulty during laparoscopic cholecystectomy affected operative time and outcomes. They concluded that complex cases increase the

likelihood of instrument exchanges and interruptions, thereby prolonging surgery and increasing complication rates. For complex laparoscopic cases, surgeons should anticipate technical challenges and attempt to minimize operative time by optimizing instrument usage to reduce complication rates.

Miller *et al.*⁸ simulated several common laparoscopic surgeries using a box trainer and reported data on instrument usage and exchanges (Table 1). A prospective clinical trial by Stotz *et al.*²⁶ studied instrument utilization and switching patterns in laparoscopic gynecologic surgery and found that laparoscopic surgeons handle an average of 12–15 different instruments per procedure. Key statistics on switching these instruments included:

- (i) Median of 51 switches per surgery (range: 2–250).
- (ii) Each switch lasted a median of 0.13 minutes (7.8 s)
- (iii) Cumulative instrument switching time was 6.83 minutes per procedure, accounting for 10.5% of total operation time.

This additional physical strain led to increased grip strain and hand fatigue from constant tool manipulation, repetitive stress injuries affecting the fingers, wrists, and forearms, and cumulative strain from inefficient instrument designs, particularly those with high force-activation requirements.

Jung *et al.*²⁷ investigated device-related interruptions in MIS and found

these disturbances were common, occurring in 30% of cases. Major causes of these workflow disruptions included device handling, such as being handed the wrong device, improper device assembly, or loss of sterility. Interestingly, the procedures with the highest device-related interruption rates were laparoscopic sleeve gastrectomy (52%) and laparoscopic oncologic gastrectomy (43%), highlighting the importance of streamlined workflow in foregut surgery. In fact, some high-volume bariatric centers now justify using two separate laparoscopic staplers during sleeve gastrectomy, constantly rotating a newly reloaded stapler to reduce instrument exchange time and lower overall operative time and cost.

Lastly, frequently passing multiple tools among team members inherently introduces the risk of miscommunication, particularly in high-stress environments. Surgeons frequently experience frustration when the wrong instrument is provided, when tool handovers are delayed, or when inconsistencies arise due to team rotations and unfamiliarity with surgeon preferences. Communication failures have been identified as the primary cause of >70% of sentinel events in surgical settings. Instrument exchanges require the surgeon to refocus visual attention from the surgical field to the instrument tray, adjust hand positioning, interrupting procedural continuity, and retrain muscle memory for each new instrument, increasing cognitive workload. These findings

Table 1. Simulated laparoscopic instrument use during common procedures using a box trainer

Laparoscopic procedure	Total number of instruments	No. of instrument changes
Cholecystectomy	7	24
Right hemicolectomy	3	5
Roux-en-Y gastric bypass, hiatal hernia repair, removal of gastric band	9	50
Hiatal hernia repair and vagotomy	8	31
Nissen fundoplication	7	13
Gastric tumor removal	8	21
Roux-en-Y gastric bypass	7	41
Transabdominal preperitoneal bilateral inguinal hernia	2	5

underscore the critical importance of efficient instrument exchange to minimize delays, reduce surgeon stress, and enhance overall surgical performance.

The effect of frequent instrument exchanges on patient safety

Mismanagement of an extracorporeal instrument exchange also increases the risk of contamination, as each additional handoff between OR staff introduces another opportunity for bacterial transfer. With each instrument exchange, there is also an opportunity to drop it or inadvertently touch the non-sterile field.

In addition to contamination concerns, exchanging instruments outside the field of view can cause unintended tissue trauma. Laparoscopic cholecystectomy, for example, involves an average of 10 use errors per procedure, with three leading to significant patient harm. Studies indicate that 80% of these errors are attributed to improper instrument execution, a risk exacerbated by high-frequency tool exchanges. A junior surgeon typically has not developed the required muscle memory to accurately return an instrument to its previous location, resulting in either a significant pause in the operation to “find their instrument” or, worse, inadvertently stabbing abdominal viscera.

Anecdotally, in foregut surgery, it is routinely necessary to elevate the liver to expose the diaphragm and stomach. Working in this confined space with frequent instrument exchanges imposes the risk of stabbing the liver with an instrument, which not only presents risk to the patient but also complicates the procedure as the blood then drips into the operative field throughout the case, significantly prolonging the procedure. Similarly, Vallancien *et al.*²⁸ described a significant risk of colon injury when instruments are inserted through lateral trocars in pelvic urological surgery. A multifunctional instrument that decreased the overall number of exchanges through a laparoscopic port would decrease the risk of these inadvertent insertion injuries.

A NEW LAPAROSCOPIC DEVICE TO DECREASE INSTRUMENT EXCHANGES

Symphera is a new prototype of a laparoscopic multi-tool device that can switch its functional tip while remaining inside the body. While clinical trials

and FDA clearance are still needed, this unique prototype displays a fundamental shift in laparoscopic surgery by addressing the inefficiencies of traditional surgical instruments. Unlike existing solutions, which rely on frequent manual instrument exchanges, this prototype integrates automated tool switching to reduce surgical time and complications, improve workflow efficiency, and enhance surgeon focus, potentially offering a unique solution to a longstanding challenge in laparoscopic surgery that no other system has yet to address.

Overview of the device prototype

Like a multi-pen that changes colors at the press of a button, the prototype allows surgeons to seamlessly switch between up to eight instrument tips stored in an integrated magazine—without removing the device from the patient’s body (Figure 1). In pre-clinical studies, this automation has been shown to minimize the need for multiple inefficient manual instrument exchanges and reduce instrument switching time. In 2024, Symphera conducted its first preclinical validation study (not yet published) at the IRCAD center in Strasbourg, France. Seven MIS surgeons evaluated the device during three standardized tasks using excised pig stomachs in a simulated laparoscopic environment, totaling over 100 minutes of operating time (Figure 2). All participants completed the tasks successfully,

with no safety incidents. In total, 148 tool changes were performed, with a median instrument-change time of 3.4 seconds. Qualitative post-hoc analysis from the surgeons emphasized workflow efficiency, usability, and future clinical potential. A second porcine feasibility study is underway, with plans to publish this data as a peer-reviewed article upon completion.

Components and design

The system includes the following components: (i) handheld device, (ii) tooltips within a magazine (currently storing up to eight instruments), and (iii) a console with screen interface.

- (i) Handheld device: The device consists of a single-use handle and a sterilizable part, which contains the drive unit and electronics. It enables intuitive, one-handed operation, allowing surgeons to maintain vision and control over the tooltip while focusing on the procedure. The 33 cm shaft facilitates tool-tip changes through the trocar, completed in under three seconds. The device’s haptic feedback, delivered through direct mechanical coupling, preserves the surgeon’s sense of touch. This is critical for maintaining procedural quality while also accelerating tool transitions. The design accommodates both left and right-handed surgeons. Its sterilizable components may withstand up to 100 sterilization



Figure 1. Symphera prototype 4.2



Figure 2. Tissue test setup

cycles, though this will ultimately be validated by the FDA.

- (ii) Tooltips and magazine: The tooltips already comprise up to 80% of the tools traditionally required for laparoscopic surgeries, such as graspers, scissors, and hooks. These single-use tooltips are provided pre-loaded in the integrated magazine. Each magazine is specifically tailored to its respective surgical task. Surgeons can select a pre-configured magazine that holds up to eight instruments. Current tooltips include: a monopolar hook, a monopolar scissors, a monopolar Maryland dissector, a bipolar atraumatic grasper, and a retraction jaw grasper. Additional tooltips are planned for integration into the existing device to enhance its functionality.

- (iii) Console and screen interface: The console serves as the system's central hub, providing reliable connectivity among the handheld device, the screen interface, and the external high-frequency generator. The console ensures a reliable power supply for the handheld device. The additional interface allows the surgeon to visualize tool selection in real time, providing step-by-step instructions to guide the surgeon through setup and simplifying tool selection and switching.

Potential key differentiators: A summary of the unique properties of the device

It is important to note that the reviewed device remains an investigational device and has not yet been approved by the FDA or other regulatory authorities. The potential differentiators described represent anticipated benefits that remain to be validated in

clinical studies and real-world surgical use (Table 2).

Step-by-step working procedure of the multi-tip device prototype

The following is the working flow of the multi-tip device prototype:

- (i) Setup and integration: The system can be used with the existing OR display and camera, making it compatible with most laparoscopic audio-video, boom, and monitor setups.
- (ii) Instrument selection: With the device remaining inside the body, the surgeon selects the tooltip needed for the procedure by pressing a button on the handheld device. The system displays a clear, user-friendly interface that shows all available instruments. The surgeon manually toggles through the available options and simply presses one button to confirm their choice.
- (iii) Automated tool switch: After the tool is selected, the handheld device automates the tip-switching process. The surgeon presses the single button, and the system activates the tool change. The current tool retracts into the integrated magazine, while the new tool advances through the shaft.
- (iv) Real-time monitoring and feedback: Once the tool switch is complete, the surgeon receives feedback via the device, confirming that the tool

Table 2. A summary of the unique properties of the device

Potential differentiators	Benefit/Description
Instrument change time	Automated tool switching for the prototype takes approximately 3 seconds, potentially reducing instrument change time and improving overall procedural efficiency
Multifunctional device	Up to 80% of the most used laparoscopic instruments are integrated into a single device, potentially eliminating the need for separate tool sets and reducing inventory complexity
Number of instrument exchanges	Potentially up to 100% reduction in external instrument exchanges, aiming at reducing the likelihood of errors including unintended tissue damage, miscommunication, and workflow disruptions
Gaze deviations	By automating tool changes, the system may minimize the need for surgeons to look away from the operative field, potentially enhancing focus and reducing cognitive load and stress during procedures
Operating room costs for complex procedures	May save up to 30 minutes of OR time per 120–240-minute surgery, potentially allowing hospitals to treat more patients

is securely in place. Visual feedback also appears on the interface, ensuring everything is functioning as expected. Throughout the procedure, the instrument tracks every tool change in real-time. The system records the tool's usage time, ensuring that all data is available for post-surgery analysis.

- (v) Post-surgery tool management: After the procedure, the used magazine, tooltips, and handheld portion of the device are disposed of. Pending FDA clearance, the system's reusable drive unit and electrical cord will be safely ejected, steam sterilized, and readied for reuse.

SIMULATED CLINICAL CASE STUDIES

To apply this prototype to real-world case data, five commonly performed laparoscopic surgeries of varying difficulty were selected from a single surgeon's MIS practice. The average procedure time over the past five years was tabulated. The average number and type of laparoscopic instruments used for each procedure was recorded, as well as the average number of instrument exchanges. Using this institutional data and the previously described comprehensive medical literature review in PubMed, an average number of instrument exchanges for each of these laparoscopic procedures was created. Surgeon preference was then used to pre-select the tools to include in a tailored magazine cartridge for each procedure, aiming to include as many typical laparoscopic instruments as possible (up to 8). Each procedure was then simulated as if the surgeon was using the Symphera prototype. The total number of instrument exchanges was again recorded. Suction/irrigation, camera cleaning, and passage of supplies such as needles and/or mesh were excluded as independent variables unrelated to the type of instrument used. Subsequently, it was possible to create modeled projections of the number of instrument exchanges required, and thus the reduction in OR time and cost per procedure. Time was rounded to the nearest minute. To estimate OR time costs in 2025, the 2018 *JAMA Surgery* cost estimate of \$37 per minute was used and adjusted for an average annual medical inflation rate of 2.9% (U.S. Inflation Calculator), resulting in a projected cost of approximately \$46 per minute. However, this

is likely still a conservative estimate, as recent reports from PwC's Health Research Institute suggest that medical costs may be rising faster than previously estimated. Instrument exchange time (including prolonged waits) was estimated at 20 seconds for traditional laparoscopic tools and 3 seconds for the new multi-tip prototype. A tiered reduction in the risk of complications was estimated at approximately 1% for every 1-min, 4% for every 10-min, 14% for every 30-min, and 21% for every 60-min decrease in operative time.¹³ Reduction in gaze deviation was calculated by assigning one gaze deviation per instrument exchange. The percentage reduction in gaze deviation was calculated by dividing the number of gaze deviations saved by using the multi-tool prototype by the original number of gaze deviations required for the procedure. The results are summarized in .

DISCUSSION

By eliminating time-consuming manual instrument exchanges, this novel multi-functional laparoscopic device may recover significant OR time, particularly in longer procedures. In 2002, Mehta *et al.*³ performed an in-depth analysis of laparoscopic instrument-use cycles and demonstrated that the most common sequence across all procedures was a dissect-to-clip-to-cut-to-repeat cycle. By combining all tasks in a repetitive cycle into a single multifunctional instrument, the number of instrument changes required to complete the cycle could be eliminated, thereby shortening operative time and reducing potential complications. Similar findings were observed after the development of laparoscopic bipolar scissors, leading to improved outcomes and significantly less time spent waiting or exchanging instruments compared with the standard sequence of monopolar coagulation followed by scissors cutting.²⁹

Using real-world data from a high-volume laparoscopic surgery practice, this prototype was predicted to improve operative time by 2–11%. The above findings are relatively modest compared with the existing surgical literature. Geryane *et al.*²⁴ estimated that 12 min (17%) of laparoscopic cholecystectomies were spent on instrument exchanges, compared with 9 min (11%) in this prototype simulation. There are also several studies that report that multifunctional

tools decrease overall operative time by up to 25%,^{7,8} which is higher than the 2–11% reduction observed here. There are other advanced energy devices on the market that use various forms of energy to cut, coagulate, seal, or dissect tissue, resulting in more efficient dissection and ligation than monopolar coagulation or standard dissection and ligation techniques, with fewer instrument exchanges and improved workflow. Cheng *et al.*³⁰ performed a meta-analysis of the procedural costs associated with Johnson & Johnson's Harmonic™ device versus conventional laparoscopic instruments and found that the Harmonic™ devices are more expensive upfront but reduce total costs by shortening operative times and lowering complication rates, thereby reducing overall resource utilization. While the grip strength of these advanced energy devices can be used for limited grasping and handling of tissues, they are not intended to reliably retract organs with high tension, such as gallbladders, gently handle delicate tissues like the intestine, or precisely suture or intracorporeally knot-tie. As such, avoidable instrument exchanges are still required while using these advanced energy devices, leaving room for even more efficient workflows and cost savings. Furthermore, there is a large discrepancy in the actual cost of OR time, with some more recent studies estimating up to \$113 per minute, making a direct comparison with the \$46-per-minute estimate used in this calculation quite difficult. As such, the true cost savings of the Symphera System will remain unknown until it is more widely implemented in clinical practice.

Notable limitations of the above findings are that they are based on estimated, averaged, simulated, and/or anecdotal data drawn from a single surgeon's experience, which introduces error and limits generalizability. The results are modeled projections based on workflow simulation and expert consensus, not measured clinical outcomes. Modeled projections do not always reflect measured outcomes and empirical findings. Moreover, the references used have limitations of their own, as many are small in size (*n*) and retrospective in nature. This is largely due to the paucity of literature surrounding a new surgical prototype. Clinical trials are absolutely needed to validate these findings. Lastly, cost estimates do not include maintenance and

Table 3. A comparison between real-world data and surgical simulations with the multi-functional device prototype

Laparo-scopi-c procedure	Instruments used (mean)	Number of instru-ment ex-changes (mean)	Proce-dure time (median)	Number of exchang-es using prototype	Time saved using prototype	Value of operating room time saved using prototype	Complica-tion risk reduction using prototype	Reduction in gaze devia-tion
Cholecys-ectomy	<i>n</i> = 6: • Retraction jaw grasper × 2 • Monopolar hook • Monopolar Maryland dissector • Clip applier • Monopolar scissor	27	83 mins	4	9 mins (11%)	\$414	3%	85%
Bilateral in-guinal hernia repair	<i>n</i> = 5: • Retraction jaw grasper × 2 • Monopolar scissors • Needle driver × 2	10	129 mins	0	3 mins (2%)	\$138	2%	100%
Right hemi-colectomy	<i>n</i> = 9: • Retraction jaw grasper × 3 • Monopolar scissors • Monopolar Maryland dissector • Needle driver × 2 • Advanced energy device • Stapler	14	165 mins	8	4 mins (2%)	\$184	2%	43%
Paraesoph-ageal hernia repair & fun-duplication	<i>n</i> = 7: • Retraction jaw grasper × 3 • Advanced energy device • Needle driver × 2 • Monopolar scissor	44	143 mins	5	14 mins (10%)	\$644	6%	89%
Gastric by-pass & paraesoph-ageal hernia repair	<i>n</i> = 9: • Retraction jaw grasper × 3 • Needle driver × 3 • Clip applier • Advanced energy device • Stapler	56	240 mins	9	18 mins (7%)	\$828	8%	84%

sterilization costs, nor the price of the Symphera System, which is currently unknown in the pre-market state and beyond the scope of this paper.

Alongside this work, other technological advances are evolving to improve efficiency, safety, and personalization in MIS. Robotic platforms and AI-assisted instruments are increasingly being developed to enhance workflow efficiency, reduce operative time, and support surgical decision-making.³¹⁻³³ In parallel, three-dimensional printing has moved beyond its role in producing anatomical models for education and preop-

erative planning and is now being used to design and prototype surgical instruments themselves.³⁴ Additive manufacturing offers rapid iteration, ergonomic customization and cost-effective testing of functional prototypes, thereby accelerating innovation cycles.

Future directions for this novel multifunctional tip-exchanging technology could focus on robotic surgery, where surgical tool exchange is a major hindrance to OR efficiency. With current popular models, robotic tool exchange requires verbal instructions to an assistant and a surgical scrub tech, as well

as an additional step of uncoupling the instrument from the robotic arm, which adds time to the exchange process. There is also great potential in adding the device to the rapidly developing field of hybrid robotic surgery, where existing laparoscopic instruments are currently controlled by third-party robotic platforms. Lastly, one of the more appealing features of this system is that, once cleared by the FDA, it can be used immediately and integrated into any hospital's existing workflow. Most hospital administrators must thoughtfully and equitably allocate robotic OR

time to their surgeons, which can create bottlenecks in surgeons' access to robotic surgical tools, delaying throughput. However, this novel multifunctional device adds to the surgeon's toolbox, increases efficiency, and offers data analytics and feedback like a robotic platform; it does not require dedicated OR time and therefore eliminates many of the surgeon access issues found with robotic platforms.

CONCLUSION

This narrative review highlights the importance of integrating modern practices and tools to improve outcomes for both patients and healthcare providers. Based on modeled projections from clinical data and surgical simulations, this novel laparoscopic surgical multi-tool prototype may add measurable value to the field of laparoscopic surgery by minimizing instrument exchanges, reducing operative time, and addressing factors such as surgeon fatigue and device-related interruptions. This would collectively improve surgical efficiency, reduce complications, and decrease healthcare costs. The relative benefit of this device increases with prolonged cases, particularly in confined spaces such as the hiatus and pelvis where blind tool switching can be most dangerous. As surgical technology and innovation continue to advance, we will face future challenges in weighing the cost of a new tool against the value of its use. While the early design and modeling work are promising, prospective clinical evaluation and peer-reviewed validation are required before any definitive claims regarding clinical or economic impact can be made. If cleared by the FDA and clinical trials ultimately support the above findings, this valuation must include much more than the cost of the tool.

AUTHORS' DISCLOSURE

The author is a paid consultant for Symphera and received compensation related to the research and preparation of this manuscript. Although the manuscript evaluates a Symphera surgical device, all aspects of the study, including its design, methodology, conduct, analysis, interpretation, and reporting, were performed independently by the author. Symphera did not influence the study design, methodology, conduct,

data interpretation, manuscript content, or publication decisions.

CONFLICT OF INTEREST

Brett Parker is a paid medical consultant for Symphera, who provided general support for the author's time on the work, though had no interference with the author's ability to analyze and interpret the data.

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