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Comparison of 8 and 5 mm robotic instruments in small cavities

5 or 8 mm robotic instruments for small cavities?

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Abstract

Introduction Robotic surgery has seen increasing use in the field of pediatric surgery. Our clinical experience suggested instrument size can impact on the surgical ability. This study aimed to compare the performance of robot-assisted laparoscopic skills in confined spaces using either 5 or 8 mm instruments.

Methods A preclinical randomized crossover study design was implemented. 24 assessors performed three different reproducible drill procedures (M1: peg transfer, M2: circle cutting, M3: intracorporeal suturing). To assess surgical proficiency in confined working spaces, these exercises were performed with 5 and 8 mm instruments of the da Vinci® Surgical Systems Si in a cubic box with 60 mm-sized edges. Each performance was recorded and evaluated by two reviewers using both objective structured assessment of technical skills (OSATS) and global evaluative assessment of robotic skills (GEARS) scores. Parietal iatrogenic impacts and instrument collisions were specifically analyzed using a dedicated scoring system.

Results Regardless of their experience, trainees performed significantly better when using 8 mm instruments in terms of OSATS scores (20.5 vs. 18.4; $p < 0.01$) and GEARS scores (23.4 vs. 21.9; $p < 0.01$) for most items, except for " depth perception" and "autonomy." The 8 mm performances involved significantly less parietal box damage (4.1 vs. 3.4; $p < 0.01$), and tool collisions (4.1 vs. 3.2; $p < 0.01$).

Conclusions In light of the better performances with 8 mm tools for specific tasks and parietal sparing constraints in restricted spaces, this study indicates that 5 mm instruments can be deemed to be less effective for reconstructive procedures in small children.

Keywords Robotic instruments · Pediatrics · Small children · Surgical skills

Robotic technology is increasingly gaining acceptance in the field of pediatric surgery, and particularly in pediatric urology [1]. Meehan et al. were the first to describe the concept of robotic surgery for small children [2], and they defined a body weight cut-off of 10 kg for this group of patients. Studies involving large series have confirmed the feasibility of such surgical procedures for these patients [3], although they have also highlighted technical difficulties in certain neonatal indications, such as a definitive minimal body weight limit of 3 kg [2]. Technical limitations include collision of the instruments, lack of room to work properly, and consecutive iatrogenic wall traumas. According to results obtained from an experimental study [4], no task can be performed in a space smaller than a cubic box with 40 mm edges due to severe external collisions of the robotic arms.

Many studies in the recent literature have reported individual experiences regarding the use of the da Vinci® platform, using either 5 mm [5] or 8 mm [6, 7] diameter instruments. Each of these studies has provided convincing arguments for use of such instruments with the pediatric patients. However, based on our surgical experience,

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particularly while performing fine reconstructive tasks in restricted spaces, use of these two instruments appeared to differentially take advantage of the merits of the EndoWrist® system, and thus offered differing technical advantages of the robotic technology. In order to make an objective comparison of the operative performance of da Vinci® Surgical System instruments, an experimental study was conducted using 5 mm versus 8 mm instruments in a limited workspace.

Materials and methods

Robotic equipment

The third generation of da Vinci® Surgical Systems Si equipped either with 5 or 8 mm diameter instruments was used to perform drills in a cubic-framed box (Fig. 1). Three da Vinci instruments of 5 and 8 mm, respectively, were selected: DeBakey Forceps (Ref. 420145/420036), a Needle Driver (Ref. 420117/420006), and Round Tip Scissors (Ref. 420117/420007). These three instruments were selected as they are very similar despite their different diameters.

A cubic box with 60 mm edges was selected, based on a preliminary study that determined that this represented the minimum size for performing tasks without major collisions. These findings confirmed those reported in the study of Thakre et al. [4]. The trocar port placement and robot configuration were calculated to optimize the overall isotropy index of the robot [8].

Subjects

A total of 24 participants were enrolled in this study, including 14 medical students, seven surgical residents, and three experienced surgeons. The medical students had no prior experience with robotic platforms. The surgical residents had experience with laparoscopic surgery, although not with robotic systems. The three experienced surgeons had prior experience with standard laparoscopy and robotic platforms.

Simulation exercises

Three drills were selected from the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills [9]: the peg transfer (M1), the circle cutting (M2), and the intracorporeal suturing bean drop drill (M3). These were chosen because they were presumed to allow for assessment of the entire spectrum of reconstructive surgery procedures. M1 was performed using two DeBakey Forceps. M2 was performed using DeBakey Forceps and round tip scissors. M3 was performed using DeBakey Forceps and a needle driver.

Experimental protocol

Each drill (M1–M2–M3) was performed three times by each assessor. The magnification and scaling image were kept constant throughout the drills. All of the assessors were randomized into two equivalent groups: group A and group B, no confounding factors such as surgical or video gaming

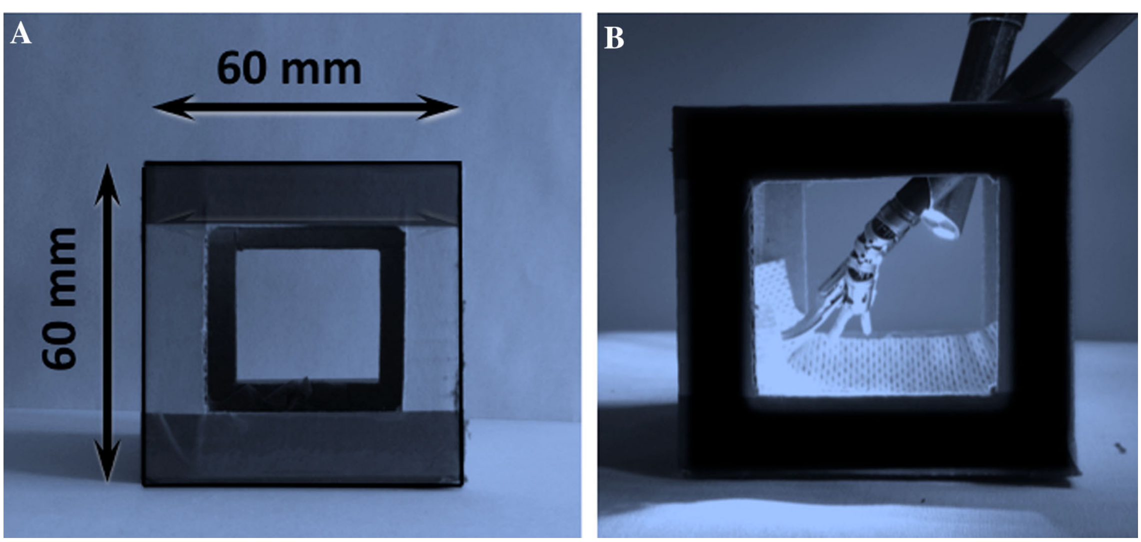

Fig. 1 **A** Lateral view of the *cubic cardboard box* with 60 mm edges. **B** da Vinci® robot setup with 5 mm instruments in the *cubic box* with 60 mm edges

experience and the proportion of left-handed participants were found. Group A participants were asked to perform all of the drills first with 5 mm instruments followed by all of the same drills using 8 mm instruments. Group B first performed the tasks with 8 mm instruments and then with 5 mm instruments, so as to create a crossover. After oral and written information, each participant was given an explanation of the three drills for orientation that lasted 5 min. They were allowed to practice for 3 min before undertaking the task involved for each drill. During the procedure, external assistance was available from an instructor who was present in case of difficulties. Each task was videotaped using Studiocode® Microsoft software (Vosaic®, Lincoln, Nebraska, USA), which allowed instant recording of the eventual need for external assistance. The performance was then evaluated by two independent senior reviewers.

Scoring

The primary endpoint was to assess the global operative performance evaluating three main points: the final product, the technical feasibility, and the iatrogenic trauma to the wall. Time required for successful completion was recorded. The performances were then objectively scored in regard to each task. OSATS scores [10] were used to evaluate the final product and the surgical skill. GEARS scores [11] were used to assess the robotic surgical proficiency. As both of these do not specifically take into account wall impacts in a confined workspace, a specific parietal iatrogenic score was designed (Fig. 2). For this purpose, a cardboard box lined with paper (Fig. 3) was used in order to count the number of impacts or tears. As shown in Fig. 2, a decrease in the impacts and collisions was related to improved surgical performance, which was reflected as higher scores.

Statistical analysis

Statistical analyses were performed using prism 5® Microsoft (GraphPad software, San Diego, California, USA). A paired t test and Mann–Whitney test were used to compare the 5 and 8 mm overall scores. An ANOVA test was performed to compare the three subgroups of assessors. A p value of ≤ 0.05 was considered to be statistically significant. Using a questionnaire, at the end of the evaluation each participant was asked about the level of difficulty for each drill and in accordance with the type of instruments. The institutional review boards of the authors' institutions approved this study.

Results

Of the trainees, 71% were males and 29% were females, with a median age of 26 years, ranging from 21 to 37 years of age. In all, 432 task performances were analyzed for the 24 assessors. The overall surgical performance was statistically better for each drill when using the 8 mm robotic instruments, as compared to the 5 mm ones.

For the M1 drill, the median time for completion was not statistically different for the 8 mm group (147 (50–340) vs. 160 (55–320) s ; $p = 0.06$). In terms of the OSATS score, use of 8 mm instruments resulted in statistically significantly higher scores for both M2 (20.1 vs. 18.0; $p < 0.01$) and M3 (20.8 vs. 18.9; $p < 0.05$) as compared to with 5 mm instruments (Fig. 4). This better overall performance with 8 mm instruments was also observed when focusing on the individual OSATS items. Thus, using 8 mm instruments, the scores were significantly higher for each item, with the exception of the "knowledge of experience" item (Fig. 5).

In regard to GEARS scores, global performances were statistically significantly better when using 8 mm instruments, as compared to 5 mm ones for the M1 (23.9 vs. 22.2; $p < 0.01$), M2 (23.7 vs. 22.1; $p < 0.01$), and M3 (23.1 vs. 21.6; $p < 0.01$) drills. Each GEARS item had a significantly higher score when 8 mm instruments were used, except for depth perception and autonomy tasks (Fig. 6).

Fig. 2 **A** Parietal impact scores. **B** Instrument collision scores

(A)

1	2	3	4	5
Major box trauma Deep impacts or tears		Superficial impacts Box minor deformation		Minor contact with box parietal integrity of the box

(B)

1	2	3	4	5
Permanent collisions Preventing to complete entire task		Occasional collisions occasional need to relocate arms		Minimal collisions

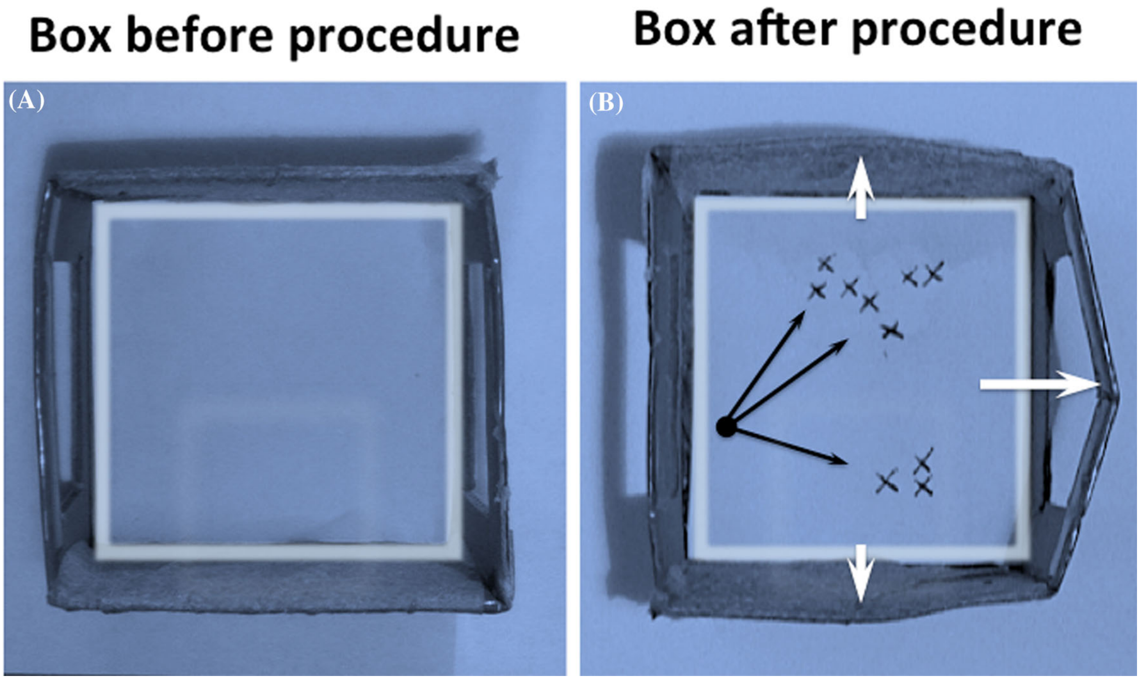

Fig. 3 Examples of parietal constraints. **A** The *cubic cardboard box* with 60 mm edges, as viewed from above. **B** View of the *box* after the robotic procedure, showing pronounced parietal impacts (*black arrows*) and clear wall deformations (*white arrows*)

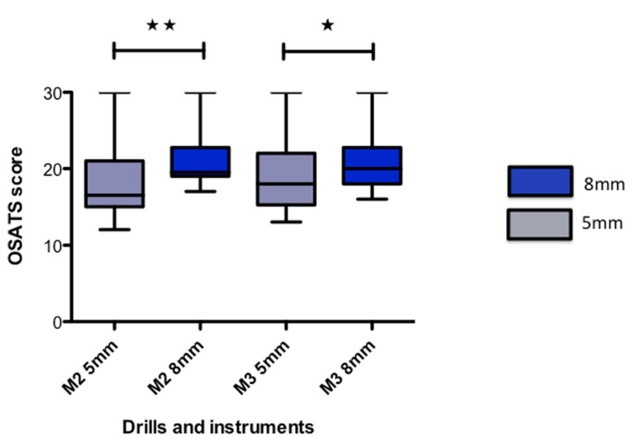

Fig. 4 Mean OSATS scores, with standard deviations, for M2 and M3 drills with respect to the instrument size. 8 mm instruments scored significantly better for foam cutting (M2: 20.1 vs. 18.0; $p < 0.01$) and the suturing drill (M3: 20.8 vs. 18.9; $p < 0.05$), as compared to 5 mm instruments. $^{**}p < 0.01$ and $^{*}p < 0.05$

For the surgical feasibility based on global instrument collision scores, use of 8 mm instruments resulted in significantly higher scores than with the 5 mm one for all three drills (4.1 vs. 3.2; $p < 0.01$) (Fig. 7A). Regarding parietal scores, the 8 mm group also scored significantly higher, as compared to the 5 mm group (4.1 vs. 3.4; $p < 0.01$) (Fig. 7B).

As expected, experienced surgeons exhibited better overall performances for the various scores, as compared to the surgical residents and the medical students. This difference was particularly noticeable when using the wall impact scores, with higher score both for 5 and 8 mm instrument use (Fig. 8). Surprisingly, on the final and anonymous satisfaction questionnaire, of the 24 assessors, 66% claimed to have a better surgical feeling using the 5 mm instruments (no statistical difference).

Discussion

This study reports our findings regarding the better performances with 8 mm instrument use for specific tasks and parietal sparing constraints in restricted spaces. To our knowledge, this is the first comparison of these two types of da Vinci® Surgical System instruments.

The most significant finding is the better performances in terms of instrument collision and parietal impacts with 8 mm instruments. These parameters have not been studied previously and we believe that they critically determine the post-operative course in regard to pain. These parameters are difficult to quantify during live procedures, and particularly by non-experienced surgeons. The latter may explain the absence of a correlation between objective performance and the feel for the instruments that was reported by this group of novices in the questionnaire.

As expected, the size of the instruments had no effect on the specific “depth perception” and “autonomy” GEARS items. The better performances with 8 mm instruments for

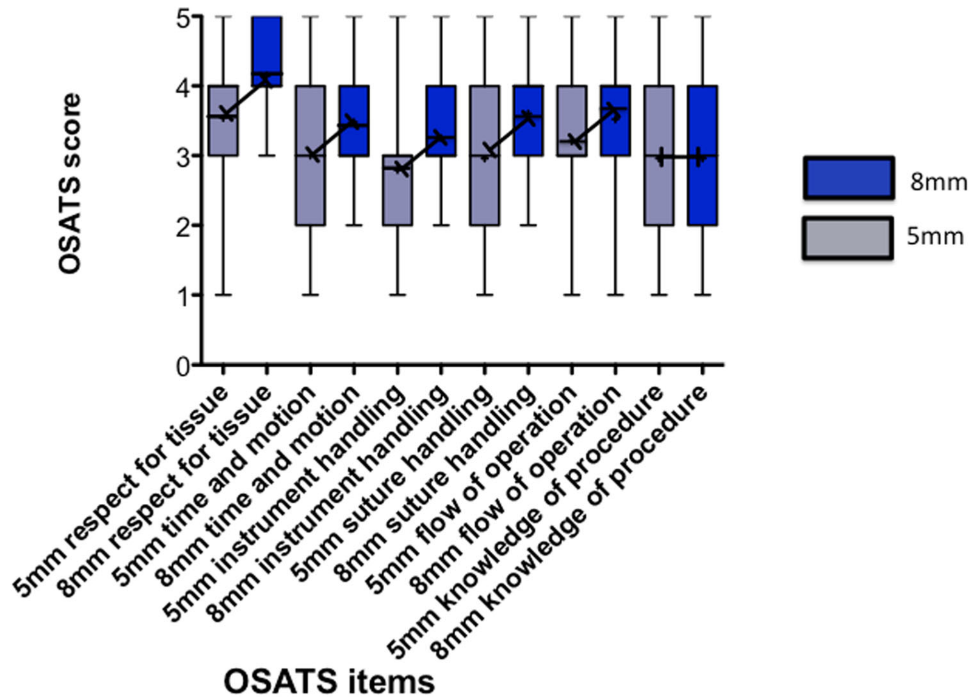

Fig. 5 OSATS score details highlighting each mean OSATS item score, with standard deviations, with respect to instrument size. 8 mm instruments scored significantly better for each item, with the exception of the "knowledge of experience" item

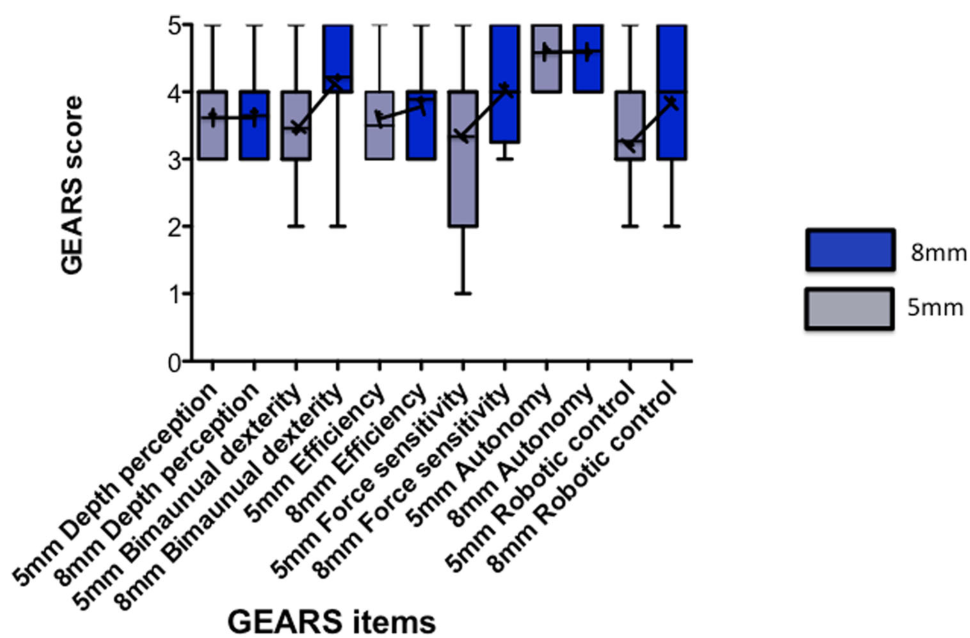

Fig. 6 GEARS score details highlighting each mean GEARS item score, with standard deviation, with respect to instrument size. 8 mm instruments scored significantly better for each item, with the exception of the "depth perception" and "autonomy knowledge" items

the item "efficiency" may be the result of the robotic controls. The better performance of the 8 mm group for the item "robotic control" shows the results were consistent with the dedicated collision instrument score. The item "force sensitivity" may have a direct repercussion on the different OSATS items, except "knowledge of procedure." In the same way, decreasing instrument collisions and increasing robotic control may directly affect the rate of the parietal iatrogenic impacts.

For the present study, the choice of assessors included medical students and surgical residents. Inclusion of users without prior robotic experience is the main limitation of this study given the consideration of generalizability. Naive users are not aware of the dangerous or inadequate procedures, although those parameters were quantified by the dedicated scoring system. Conversely, a complete absence of experience with robotics makes their performances more comparable. Inclusion of medical students has been

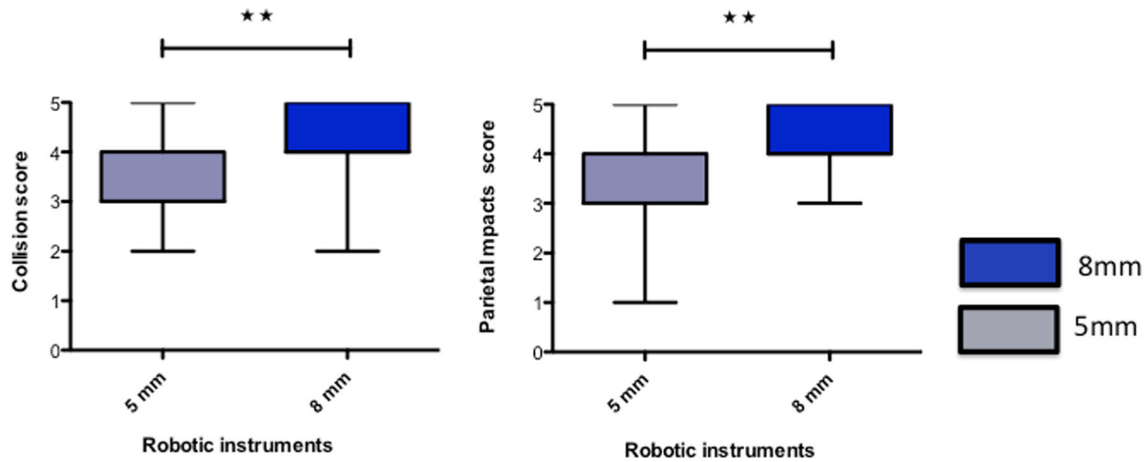

Fig. 7 Instrument collisions and parietal impact results. **A** Global instrument collision scores were significantly higher for 8 mm instruments, as compared to 5 mm instruments for the three drills (4.1 vs. 3.2; $p < 0.01$). $^{**}p < 0.01$. **B** Global parietal impact scores were significantly higher for 8 mm instruments, as compared to 5 mm instruments for the three drills (4.1 vs. 3.4; $p < 0.01$). $^{**}p < 0.01$

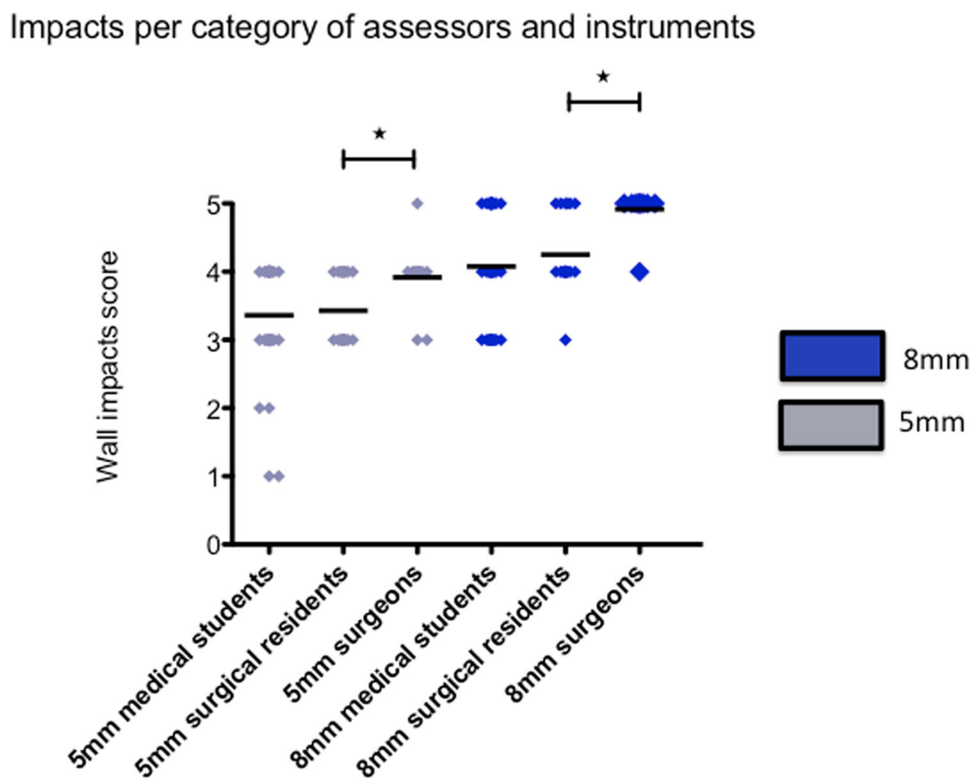

Fig. 8 Overall parietal impact score with respect to assessors' category and instruments size. Mean scores and performance increase with the experience of the assessor whatever the type of instruments. Statistical difference was found between surgeons and surgical residents for both 5 mm (3.9 vs 3.5; $p < 0.05$) and 8 mm (4.9 vs 4.2; $p < 0.05$) instruments. $^{*}p < 0.05$

reported in many prior experimental surgical studies [12]. The learning curve effect was addressed by the crossover study design, as described previously [13]. Experienced trainees with prior robotic experience performed better compared to other trainees, regardless of the instruments and the exercise tasks, although comparison of the subgroups was not emphasized in light of the low proportion of experienced surgeons. A higher proportion of pediatric surgeons with robotics experience would probably lead to more blunted results. In the present model, the overall tendency for better performances with more experienced assessors confirmed that the degree of reproducibility was adequate. The results for users with no robotic experience are potentially transferable to pediatric surgeons with the intention of implementing robotic pediatric surgery in their team.

Some authors have stated that 5 mm instruments offer advantages in regard to pediatric patients, due to their smaller diameter and the finer needle forceps for grasping. This advantage has been clearly demonstrated for pediatric thoracic surgery, where there is a limited width in regard to the intercostal space [14]. Thus many studies [5] dealing with fine surgical structures report excellent results while also reporting satisfactory technical sensation. The objectivity of this argument is however questionable in light of the divergence between questionnaire and performances in the present study.

The cut-off size limit for children to be considered appropriate candidates for robotic intervention is still a matter of debate. As the size of patients decreases, the risks of instrument collisions and parietal traumas increase, as do the technical difficulties and the console time [6]. Size constraints are the main limitation for the development of this platform for pediatric surgery applications [14, 15]. There is currently no consensus as to which infants can safely undergo robotic surgery. The workspace has a major impact on the performance of pediatric urology procedures. Finkelstein et al. [6] proposed a minimal distance of 13 cm between the anterior iliac spines and a 15 cm puboxyphoid distance as a cut-off for case selection. These dimensions, which correspond to 6-month-old patients, appear to be considerably more than the 60 mm cubic box used here to represent the abdominal workspace of a neonate.

Most of the recent series involving small children have reported using 8 mm instruments with a purported improved mobility, although no significant case has been published to prove its superiority. The 5 mm instruments were presumed to need more space to operate due to their typical joint kinematics [4]. Specific tasks in restricted spaces require acute angulations at the terminal joint. In a limited workspace, 8 mm instruments can readily achieve such acute angulations, as compared to 5 mm ones.

For the first time, this study illustrates the paradoxical space-consuming effect of 5 mm instruments as compared to 8 mm ones. It confirms the technical differences of the instruments, advocating better performances for the 8 mm diameter ones, with fewer collisions and parietal sparing constraints in confined workspaces. Consequently, we recommend the preferential use of 8 mm instruments in small abdominal or thoracic cavities whenever this is possible. The 5 mm robotic instruments may nonetheless still offer case-specific advantages, for example, for neonatal patients with thoracic indications or who are beyond the neonatal period, for example, with the development of robotic single-site surgery [16]. In light of the low proportion of senior surgeons among the participants, the main limitation of this study is the transferability of the present results to pediatric surgeons experienced with robotics.

Conclusion

These results indicate that 8 mm robotic instruments are safer and more efficient tools for robotic surgery in small workspaces. Although 5 mm instruments should theoretically be more appropriate for use with pediatric patient populations, our study has shown conversely that they can be less effective due to a space-consuming effect. Consequently, they provide limited capacity for reconstructive procedures in small children in light of the better performance of 8 mm tools for specific tasks and parietal sparing constraints in restricted spaces.

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Compliance with ethical standards

Disclosures Quentin Ballouhey, Pauline Clermidi, Jérôme Cros, Céline Grosos, Clémence Rosa-Arsène, Claire Bahans, François Caire, Bernard Longis, Roxane Compagnon, and Laurent Fourcade have no conflicts of interest or financial ties to disclose.

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