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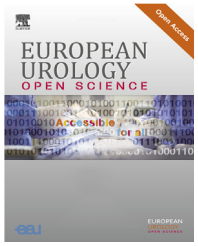

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Education

Prior Robotic Console Expertise May Improve Basic Skills at the New Hugo RAS Simulator: Results from a Cohort Trial and Implications for Skill Transference Across Platforms

Maria Chiara Sighinolfi [a,b,*], *Stefano Terzoni* [c], *Elena Scanferla* [a,b], *Pietro Paolo Bianchi* [d], *Giampaolo Formisano* [d], *Gaetano Piccolo* [d], *Matteo Barabino* [d], *Andrea Pisani* [d], *Adelona Salaj* [d], *Giorgia Gaia* [e], *Anna Maria Marconi* [e], *Filippo Turri* [a,b], *Mattia Sangalli* [a,b], *Stefano Centanni* [b,f], *Matteo Stocco* [b,f], *Davide Chiumello* [g], *Simone Assumma* [a,b], *Luca Sarchi* [a,b], *Tommaso Calcagnile* [a,b], *Enrico Panio* [a,b], *Angelica Grasso* [a,b], *Paolo Dell'Orto* [a,b], *Nicolo Maria Mariani* [d], *Clemente Verrusio* [d], *Alessandro Baisi* [h], *Giorgio Bozzini* [i], *Bernardo Rocco* [a,b]

[a] *Unit of Urology, Department of Health Science, La Statale University of Milan, Milan, Italy;* [b] *ASST Santi Paolo and Carlo, Milan, Italy;* [c] *San Paolo Bachelor School of Nursing, ASST Santi Paolo e Carlo, Milan, Italy;* [d] *Unit of General Surgery, ASST Santi Paolo and Carlo, Milan, Italy;* [e] *Unit of Gynecology, ASST Santi Paolo and Carlo, Milan, Italy;* [f] *Department of Health Sciences, La Statale University of Milan, Milan, Italy;* [g] *Unit of Anesthesiology, ASST Santi Paolo and Carlo, Milan, Italy;* [h] *Unit of Thoracic Surgery, ASST Santi Paolo and Carlo, Milan, Italy;* [i] *Unit of Urology, ASST Lariana, Como, Italy*

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Abstract

Background: Robot-assisted surgery ensures minimal invasiveness; since the expiry of the Da Vinci patent, new robotic systems have entered the market. Recently, the Hugo RAS received CE approval for several surgical procedures. However, more is needed to know about skill acquisition at the new simulator.
Objective: This study aims to analyse the factors impacting basic surgical skills at the Hugo RAS simulator.
Design, setting, and participants: We present a cross-sectional study involving 71 participants of different backgrounds invited to a hands-on session with the Hugo RAS simulator voluntarily. All of them had no prior expertise with the system. Participants were recruited among medical/nurse students, residents, and laparoscopic and robotic surgeons.
Intervention: All participants underwent a hands-on "pick and place" exercise at the Hugo RAS simulator; the metrics of a second-round pick and place exercise were recorded.
Outcome measurements and statistical analysis: Metrics were analysed with regard to the following variables: demographics, videogame use, and prior surgical experience (no surgical expertise, experience with laparoscopy, and experience with robotic console).
Results and limitations: All participants completed the test. Of them, 77.5% were naïve to surgery, 8.5% had prior laparoscopic expertise, and 14.1% had prior robotic

* Corresponding author. ASST Santi Paolo and Carlo, via Rudini 8, Milan, Italy. Tel. +39 3921329216.
E-mail address: sighinolfic@gmail.com (M.C. Sighinolfi).

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console experience. The time to complete the pick and place exercise was significantly lower ($p < 0.001$) among prior robotic surgeons (38 s, interquartile range [IQR] 34–45) compared with both naïve participants (61 s, IQR 53–71) and laparoscopists (93 s, IQR 53–162). The overall score of the exercise decreased with age ($p = 0.046$); however, the overall scores were significantly and steadily higher among surgeons experienced in robotic consoles across all age groups ($p = 0.006$). Neither gender ($p = 0.7$) nor videogame use ($p = 0.9$) correlated significantly with the metrics.

Conclusions: This is the first study analysing factors impacting basic skill acquisition at a new robotic simulator. Experience with robotic consoles may represent a major factor, raising the hypothesis of the transferability of basic robotic skills across different robotic systems. Further studies are required to explore this issue.

Patient summary: In the present study, we analysed which characteristics may affect the basic surgical skills at a novel robotic platform.

1. Introduction

Robot-assisted surgery has been established as a technology ensuring minimal invasiveness while overcoming the limitations of conventional laparoscopy. The first Da Vinci was approved for human use in 2000 by the US Food and Drug Administration. However, since the patent's expiry, novel robotic contenders have recently emerged to reduce costs and improve the accessibility to robotic surgery. These new systems are expected to maintain most of the Da Vinci characteristics (enhanced three-dimensional [3D] vision, magnification, and dexterity) while displaying some typical features, such as the open console or the presence of separate carts/bedside units for port placement. Given these differences, novel systems require a dedicated setup and training to achieve implementation. As for Da Vinci, new robots are provided with simulators for acquiring robotic skills, such as speed, workspace efficiency, and force, and for tracking the acquisition of robotic performance.

Whereas several studies analysed skills and surgical proficiency with the Da Vinci Skills Simulator (Intuitive Surgical, Sunnyvale, CA, USA) [1–4], few data are available for simulators of new robotic systems.

This study aims to evaluate the performance of participants of different backgrounds during their first experience with the Hugo RAS simulator. The new Hugo RAS system (Medtronic, Minneapolis, MN, USA) has recently received European CE mark approval for gynaecological, urological, and general surgery procedures in adults [5]. It displays some differences from Da Vinci: it consists of a single system tower with a Valleylab electrosurgical generator, an open console, and four independent arm carts. For console operators, hand controllers have a new "pistol-like" design and 3D glasses are required for surgical vision. We sought to analyse the factors impacting basic surgical skills at the Hugo RAS simulator.

2. Patients and methods

This cross-sectional study was performed at the ASST Santi Paolo and Carlo, Milan, Italy. This tertiary referral centre has two Da Vinci surgical systems, Hugo RAS and Versius robotic platforms. The latter were settled up in October 2022. Seventy-one participants of different backgrounds were invited to participate in a hands-on practice test with the Hugo RAS simulator (Mimic Technologies) voluntarily. All of them had no experience with the Hugo RAS simulator. Participants were recruited from among medical students, nurse students, residents of different surgical disciplines, laparoscopic surgeons, and robotic surgeons. Students were invited during academic courses. On enrolment, participants were surveyed about the following variables: (1) baseline demographics (age, gender, and qualification), (2) prior experience with videogames (0 = no experience, 1 = intermediate level, and 2 = advanced level/frequent users), and (3) prior surgical experience (no surgical expertise, defined as naïve; experience in laparoscopy; and robotic console expertise, defined as at least five total cases completed at the Da Vinci console). Laparoscopic surgeons have long-lasting expertise in laparoscopy, and robotic surgeons have been involved in Da Vinci console activity for at least 1 yr.

A brief introduction to the Hugo RAS simulator was performed, explaining the screen, 3D glasses, hand controllers, and pedals. After that, hands-on practice with the "pick and place" exercise was performed by all participants to test their ability in the instrument navigation task; the exercise required participants to place letters into the correct location according to their colour (Supplementary Fig. 1). After completing the first exercise, the metrics of a second-round pick and place exercise were recorded for each participant. The following variables were collected: time to exercise completion (in seconds), economy of motion (the total distance [in centimetres] travelled by all instruments), master workspace range (determined by defining a spherical volume that encloses all the positions of each master grip they are moved during the exercise; the metric reports the radius [in centimetres] of the larger of the two spherical volumes calculated for each master grip), excessive force (total time [in minutes] an excessive instrument force is applied above a prescribed threshold force), and instruments out of view. For most metrics, smaller raw values mean performing better (eg, less time, fewer drops, and fewer collisions). The overall score (the aggregate of the user's score) was recorded too, and the higher the value, the better the proficiency.

2.1. Statistical analysis

Data were collected in a deidentified format. Correlations between robotic surgery performance and background experiences and variables were analysed. Continuous variables were described as the mean and standard deviation if normally distributed (the Kolmogorov-Smirnov

test was used to assess distribution normality) or as the median and interquartile range (IQR) if not. Frequencies in contingency tables were compared with the chi-square test for independent samples or Fisher's exact test in case of expected frequencies <5. Analysis of covariance (ANCOVA) was used to test the differences between the participants (grouped by surgical experience: none, robotic console, and laparoscopy) in terms of the overall scores and the time required to complete the exercise. The model took into account age and previous experience with video games. Before performing ANCOVA, normality of data distribution and homoscedasticity (Levene's test) were performed; since the overall scores were not normally distributed, Blom's transformation [6] was used to obtain a Gaussian curve. No correction was required for the homogeneity of variances. The R-squared parameter was used to assess the goodness of fit, and an analysis of residuals was performed to exclude the existence of clinically relevant ties in the data. The effect size was calculated as Cohen's d with 95% confidence interval (CI) [7]. The significance threshold was set at 0.05 for all calculations; an analysis was performed with SAS 9.4 for Windows (SAS Inc., Cary, NY, USA).

3. Results

Seventy-one individuals participated and completed the test. Thirty males and 41 females were involved. Of the participants, 49 (69.0%) were aged 22–25 yr, eight (11.3%) were between 26 and 35 yr old, and 14 (19.7%) were older than 35 yr; women were significantly younger than men ($p < 0.001$). Fifty-five participants (77.5%) were naïve to any surgery, six (8.5%) had prior expertise with laparoscopy, and ten (14.1%) were robotic console surgeons. Laparoscopic surgeons were significantly older (median 52, IQR 45–58) than robotic surgeons (median 36, IQR 31–46) and those naïve to surgery (median 22, IQR 22–22, $p < 0.001$). Forty-one participants (58.6%) declared no significant experience with video games. Eighteen (25.5%) had intermediate expertise, and 11 (15.7%) declared solid experience or were current users. None of the participants with prior laparoscopic expertise used to play video games.

Table 1 summarises separate metrics obtained by the participants according to prior surgical experience (no experience, and laparoscopic and robotic console surgeons). The time required to complete the exercise was significantly lower ($p < 0.001$) among surgeons with prior console expertise (median 38.5 s, IQR 34.4–45.3, $p < 0.001$) compared with both naïve participants (median 60.0 s, IQR 53.0–71.5) and laparoscopic surgeons (median 94.5 s, IQR 55.5–153.0). Robotic surgeons performed better than laparoscopists in terms of economy of motion ($p = 0.01$); however, the difference was nonsignificant when compared with naïve participants ($p = 0.33$). Similarly, the overall score was higher among robotic surgeons than among laparoscopists ($p = 0.044$), whereas the difference was nonsignificant compared with naïve individuals ($p = 0.84$).

The age effect was deeply analysed with regard to separate metrics (Table 2).

The time required to complete the exercise increased—and thus impaired—with age, although the only strong independent predictor of performance remained previous console experience (partial omega-squared = 0.20, 95% CI 0.06–0.37). After adjusting the analysis by age, the time required by laparoscopic surgeons and naïve participants to complete the exercise showed no statistically significant differences ($p = 0.99$), while robotic surgeons still performed better than naïve participants ($p = 0.002$) and laparoscopic surgeons ($p = 0.004$; Fig. 1).

The overall score of the exercise impaired with age ($p = 0.046$) for all categories (naïve participants, laparoscopists, and prior robotic surgeons; Fig. 2); generally, the overall scores were significantly and steadily higher among surgeons experienced in robotic console across all age groups ($p = 0.006$).

Neither gender ($p = 0.7$) nor prior use of videogames ($p = 0.9$) correlated significantly with the overall score and time to complete the exercise metrics.

However, in a subgroup analysis excluding high-level videogame users, all surgeons, including laparoscopists, perform better than individuals naïve to surgery Overall scores ($p = 0.007$; Fig. 3). However, also in this subgroup analysis, previous expertise as a console surgeon was the variable mostly related to the overall score of the exercise and the only one to determine an effect size that could be defined as "large" (Cohen's $d = 0.55$, 95% CI 0.15–0.82).

Regarding risk and safety metrics, collisions occurred during four simulations (two collisions during two sessions, one and three collisions in one session each). Instrument drops occurred during nine sessions (one drop in seven sessions and two in the remaining); these events occurred more frequently among participants naïve to surgery than among other participants with prior laparoscopic or robotic experience ($p = 0.043$). The p values regarding the safety metrics suggested the existence of relevant differences in the performances of the three categories of participants. However, it should be noted that most people in all groups

Table 1 – Summary of the metrics stratified by prior surgical experience

Measure	No experience	Nonrobotic laparoscopic	Robotic console	p value
Time to exercise completion (s)	60.0 (53.0–71.5)	94.5 (55.5–153.0)	38.5 (34.4–56.3)	<0.001
Economy of motion	143 (132–166)	177 (162–199)	145 (129–156)	0.042
Master workspace range	6.10 (5.40–6.60)	6.30 (6.20–7.75)	6.00 (5.93–6.85)	0.2
Number of collisions	0 (0–0)	0 (0–0)	0 (0–0)	0.4
Excessive force	0 (0–0)	0 (0–0)	0 (0–0)	0.008 [a]
Out of view	0 (0–0)	0 (0–0)	0 (0–0)	0.003 [a]

Data are reported as median (quartile 1–quartile 3); Kolmogorov-Smirnov test $p < 0.05$ for most variables. The p values are generated from the Mann-Whitney test. Null hypothesis: all three groups are the same.

[a] Significant p value related to small variations in the extreme values of the variable(s).

Table 2 – Summary of the metrics stratified by age

Measure	Aged <25	Aged 25–39	Aged 40+	*p* value
Time to exercise completion (s)	60 (53–71)	50.5 (42.0–66.5)	61.5 (35.0–87.0)	0.1
Economy of motion	143 (131–164)	147.5 (136.0–156.0)	170 (133–206)	0.02
Master workspace range	6.2 (5.4–6.6)	6.1 (5.9–6.7)	6.1 (5.6–6.7)	0.7
Number of collisions	0 (0–0)	0 (0–0)	0 (0–0)	0.2
Excessive force	0 (0–0)	0 (0–0)	0 (0–0)	0.2
Out of view	0 (0–0)	0 (0–0)	0 (0–0)	0.14

Data are reported as median (quartile 1–quartile 3); Kolmogorov-Smirnov test $p < 0.05$ for most variables. The *p* values are generated from the Mann-Whitney test. Null hypothesis: all three groups are the same.

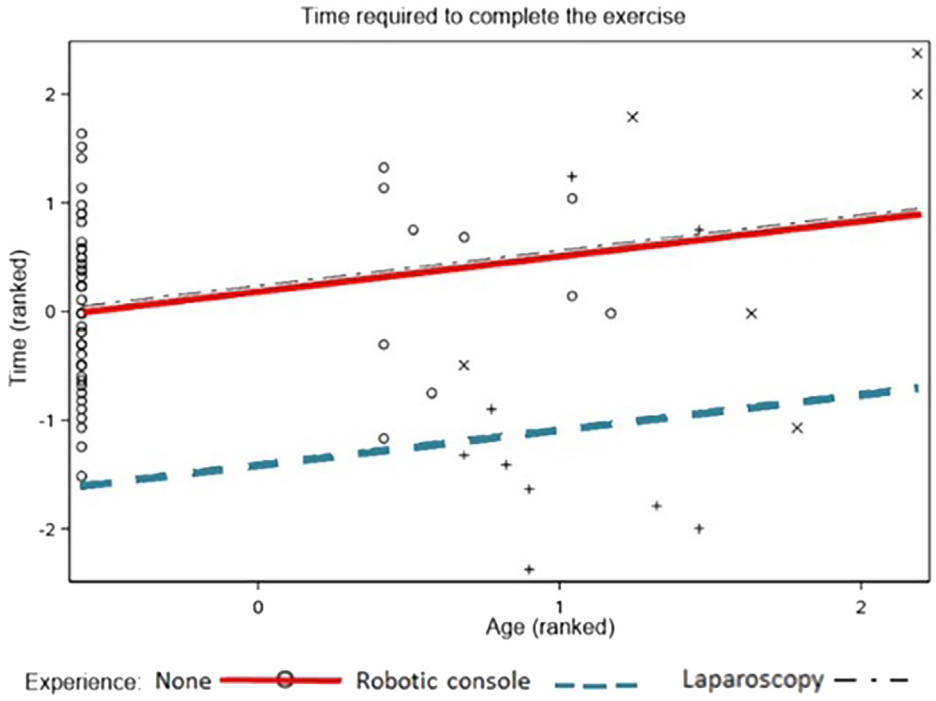

Fig. 1 – Age, prior surgical expertise, and time required to complete the exercise—a multivariate analysis (ANCOVA). ANCOVA = analysis of covariance.

scored 0, meaning that no events occurred (98.59% in the "out of view" metrics, 95.77% regarding excessive force, and 94.37% of the participants never caused collisions). These *p* values are therefore related to the remaining small percentages of participants who experienced the events during the simulation.

4. Discussion

Previous experience with the Da Vinci robot emerged as a variable impacting the time to complete a basic exercise at the novel Hugo RAS simulator; robotic surgeons performed better than laparoscopists and individuals naïve to surgery in the pick and place exercise. In addition, age represents another important variable affecting the overall score of the exercise; however, the benefit of prior console experience remained consistent across all age groups.

The role of console experience has recently been evaluated in a pilot investigation by Larkins et al. [8] to test the hypothesis that technical robotic console skills are transferrable across different robotic platforms. In this study, ten participants sequentially completed four simulation exercises on two robotic platforms (Da Vinci and Hugo RAS). The first group completed the simulation exercises on console A first and then repeated these exercises on console B; the second group completed the simulated exercise on console B and then repeated these exercises on console A. Overall, the quality and efficiency metrics and the risk and safety metrics were equivalent across consoles; the authors concluded that the overall acquired experience is equivalent regardless of the platform the participant is exposed to and introduces the issue of skill transferability across different robotic consoles [8].

Similar conclusions were stated for the training with the Versius surgical system in a preclinical setting. Butterworth et al. [9] analysed the acquisition of skill performance on 17 surgical teams participating in a structured training programme with Versius. When stratifying the achievement of skill proficiency by prior robotic expertise, those with

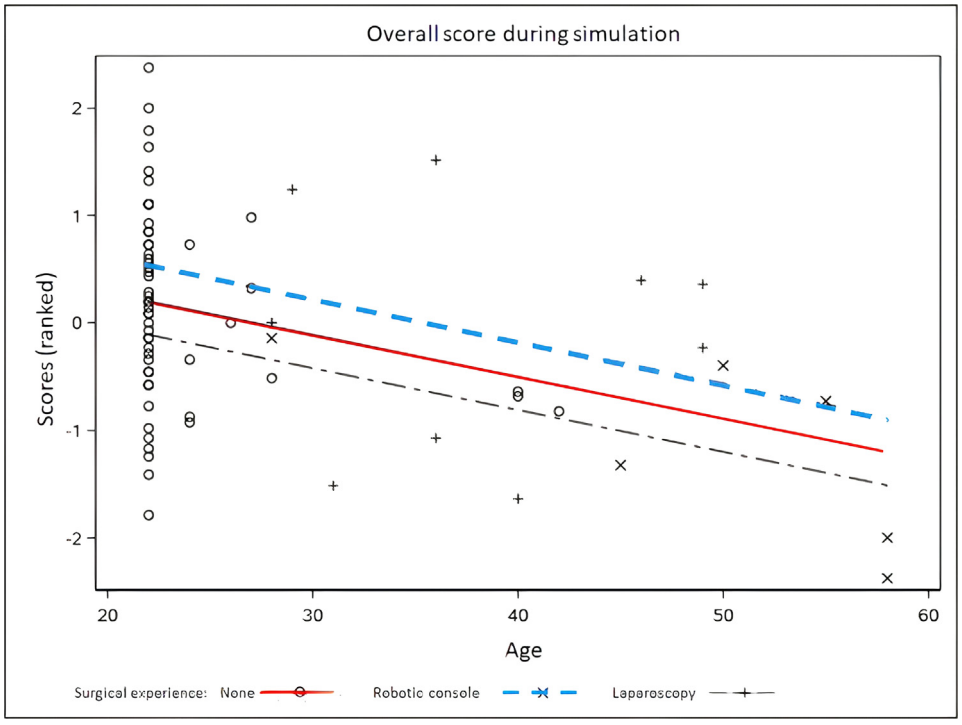

Fig. 2 – Age, prior surgical expertise, and overall score—a multivariate analysis (ANCOVA). ANCOVA = analysis of covariance.

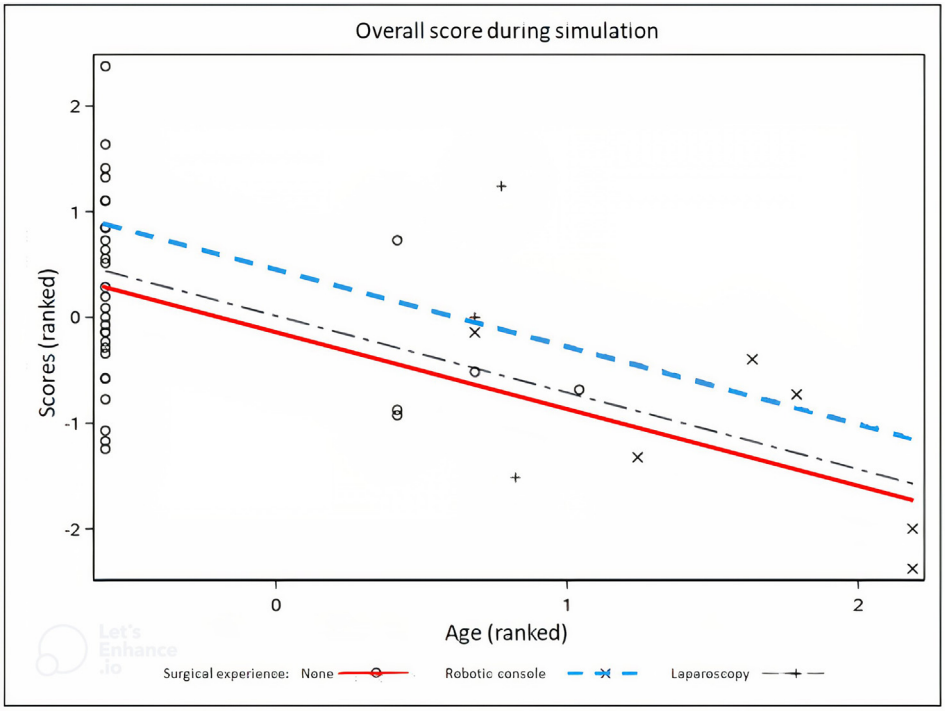

Fig. 3 – Overall score and age in participants naïve to surgery after excluding those highly experienced in videogame.

extensive prior experience scored higher than a surgeon with little or no robotic experience [9].

Introduction of new platforms will evolve robotic surgical training, and novel learning paradigms are yet to be defined. The current study raises some considerations: first, prior console expertise with Da Vinci is seemingly facilitating essential skill acquisition, such as time to complete the exercise, with new robotic systems. However, the amount

of training required by the naïve participants to reach equipoise with prior robotic surgeons is still unknown. Second, this study may reinforce the hypothesis of skill transferability across platforms. The pick and place exercise is directly comparable across both the Da Vinci and the Hugo RAS simulator, with the same metrics set for this activity [10]. Even when accounting for the difference in console feature and hand controller, prior Da Vinci surgeons had some better metric performance than robotic-naïve participants, introducing the likelihood of skill reproducibility. Third, these outcomes lead to implications for the design of multiplatform training and certification. According to Larkins et al. [8], training can safely occur across multiple consoles contemporaneously: the hypothesis of skill transference across systems, as suggested in the present article, may reinforce this concept and pave the way to new training and performance tracking models.

In the current series, prior videogame experience is not impacting the metrics of the pick and place exercise with the Hugo RAS simulator. Several studies have addressed the issue with the Da Vinci simulator, leading to conflicting results [10–14]. However, high videogame experience may be considered a confounder in participants naïve to surgery; in the subgroup analysis excluding highly experienced videogame users, prior surgical expertise—regardless of the type—is a variable favouring skill acquisition, consistent with previous studies [14,15].

Till now, a total of 25 Hugo RAS procedures were performed at our institution by experienced Da Vinci console surgeons (nine urological, eight gynaecological, and eight general intervention surgeons); no major intra- or postoperative complications were recorded, thus confirming the reproducibility of robotic skills at the new platform.

This article is not devoid of limitations. First, the limitations include the small sample size and the different proportion of naïve and surgeon participants; the difference in median age between groups—naïve laparoscopists and surgeons with prior console experience —may be considered a limitation too, even though representative of the real-life scenario. Second, the "pick and place" exercise could be regarded as too simple and unrepresentative of the whole setup of robotic skills. However, it has deliberately been chosen since it is similar across simulators [10] and represents *basic* robotic skills.

More complex exercises, such as those involving sutures, may have surely been impacted by prior robotic expertise.

Third, the present study was not designed to analyse the achievement of proficiency at repeated exercises and thus fails to track further performance acquisition.

Beyond these issues, to our knowledge, this is the first study analysing variables impacting basic skill achievement at new robotic systems [16,17]. However, further studies are required to provide insights into the training with the Hugo RAS simulator and to design new learning models accounting for the upcoming multiplatform scenery.

5. Conclusions

This is the first study that analyses the factors impacting basic skill acquisition at a new robotic simulator. Previous experience with the robotic console is seemingly a significant factor; this occurrence paves the way for the hypothesis of the transferability of basic robotic skills across different robotic systems. Further studies are required to analyse this issue and achieve knowledge about the learning curve of new robotic systems, in both the preclinical and the real-life setting.

Author contributions: Maria Chiara Sighinolfi had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Sighinolfi, Rocco.
Acquisition of data: Terzoni, Scanferla.
Analysis and interpretation of data: Terzoni.
Drafting of the manuscript: Sighinolfi.
Critical revision of the manuscript for important intellectual content: Rocco.
Statistical analysis: Terzoni.
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Supervision: Centanni, Stocco.
Other: Investigation: Bianchi, Formisano, Barabino, Pisani, Salaj, Gaia, Marconi, Chiumello, Mariani, Piccolo, Verrusio, Baisi, Bozzini. Data curation: Panio, Grasso, Dell'Orto, Sarchi, Assumma, Calcagnile, Turri, Sangalli.

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Appendix A. Supplementary data

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