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Survey on Surgical Instrument Handle Design: Ergonomics and Acceptance

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Abstract

Minimally invasive surgical approaches have revolutionized surgical care and considerably improved surgical outcomes. The instrumentation has changed significantly from open to laparoscopic and robotic surgery with various usability and ergonomics qualities. To establish guidelines for future designing of surgical instruments, this study assesses the effects of current surgical approaches and instruments on the surgeon. Furthermore, an analysis of surgeons' preferences with respect to instrument handles was performed to identify the main acceptance criteria. In all, 49 surgeons (24 with robotic surgery experience, 25 without) completed the survey about physical discomfort and working conditions. The respondents evaluated comfort, intuitiveness, precision, and stability of 7 instrument handles. Robotic surgery procedures generally take a longer time than conventional procedures but result in less back, shoulder, and wrist pain; 28% of surgeons complained about finger and neck pain during robotic surgery. Three handles (conventional needle holder, da Vinci wrist, and joystick-like handle) received significantly higher scores for most of the proposed criteria. The handle preference is best explained by a regression model related only to comfort and precision ($R^2 = 0.91$) and is significantly affected by the surgeon's background ($P < .001$). Although robotic surgery seems to alleviate physical discomfort during and after surgery, the results of this study show that there is room for improvement in the sitting posture and in the ergonomics of the handles. Comfort and precision have been found to be the most important aspects for the surgeon's choice of an instrument handle. Furthermore, surgeons' professional background should be considered when designing novel surgical instruments.

Keywords

ergonomics and/or human factors study, robotic surgery, biomedical engineering

Introduction

The field of surgery is currently undergoing drastic changes in an effort to provide less invasive solutions for patients. Laparoscopy has been adopted as the gold standard for a growing number of procedures. Novel techniques such as SIL (Single Incision Laparoscopy) and NOTES (Natural Orifice Translumenal Endoscopic Surgery) are gaining clinical importance, and applications are growing rapidly.[1] These techniques might provide several advantages over open surgery procedures such as faster recovery, shorter hospitalization, lower postoperative pain, and better cosmetic results. However, the medical community is increasingly concerned about the ergonomic disadvantages associated with such complex systems and their surgical instruments.[2] Problems range from mental stress to physical discomforts that can a posteriori lead to severe musculoskeletal disorders.[3,4] According to the Institute of Medicine (IOM), about 1.3 million Americans are seriously injured each year by adverse events involving medical products. Consequently, the US Food and Drug Administration highlights the importance of ergonomics in this field.[5] Some of these ergonomic drawbacks have been overcome with the introduction of telemanipulated robotic surgical systems, composed of 2 main elements: (1) a patient-side surgical robot (the "slave") and (2) a console from where the surgeon remotely controls the surgical robot (the "master console"). Surgeons are seated, their forearms rest on pads, and the manipulation is highly

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Table 1. Detailed questionnaire

Demographic and background data:

- Field of expertise (text box), institution (text box), age (number box), gender (M, F), country (list).
  - Years of experience in open surgery: ☐ <3, ☐ 3 to 5, ☐5 to 10 and ☐ >10.
  - Years of experience in laparoscopic surgery: ☐ <3, ☐ 3 to 5, ☐5 to 10 and ☐ >10.
  - Years of experience in robotic surgery: ☐ <3, ☐ 3 to 5, ☐5 to 10 and ☐ >10.

Discomfort and procedure duration:

- Average number of hours that surgical procedures last: ☐ <2, ☐ 2 to 5, ☐ >5.
  - Have you ever experienced abnormal amount of pain or discomfort in any of the following areas?
  - While performing open surgery: ☐ neck, ☐ shoulders, ☐ back, ☐ wrists, and ☐ fingers.
  - While performing laparoscopic surgery: ☐ neck, ☐ shoulders, ☐ back, ☐ wrists, and ☐ fingers.
  - While performing robotic surgery: ☐ neck, ☐ shoulders, ☐ back, ☐ wrists, and ☐ fingers.

Handle evaluation:

Please look at the pictures of the following handles and imagine how you will **open and close** the surgical instrument with it. Give a score from 1 to 5 to each aspect: Intuitiveness, comfort, precision and stability.

Scissors-like handle: Common needle holder for open surgery (H1 in Figure 3).

Index-Thumb control: da Vinci master gripper from Intuitive Surgical Systems™ (H2 in Figure 3).

Joystick plus index-thumb control: 3D model proposed by the authors (H3 in Figure 3).

Pistol-like handle: Real Hand prototype gripper from Novare Surgical Systems (H4 in Figure 3).

Grip between all fingers and the palm: Axial handle of a RWOLF needle holder[10] (H5 in Figure 3).

Scissors-like handle: grip between all fingers and thumb: Real Hand commercially available gripper from Novare Surgical Systems[9] (H6 in Figure 3).

Pistol-like with different finger support and index-thumb control: Ergonomic prototype from Mattern and Waller[11] (H7 in Figure 3).

Would you like to have additional commands and buttons in the instrument handle? (yes-no).

Handle preference:

- Please select the instrument handles that you prefer: (multiple selection list).
- Could you briefly explain why do you prefer those instrument handles? (text box)
- Additional comments (text box).

simplified when compared with traditional laparoscopic techniques. Still, recent studies suggest that sources of discomfort are also present in robotic surgical systems, especially neck and back muscle hardening because of the non neutral back position.[6,7] Because of these above-mentioned negative effects of the ergonomics of surgical instrument, the involvement of surgeons in the design process of new surgical instruments is central: It not only helps in the acceptance of the new device but also ensures good surgical performance while guaranteeing the safety of both patients and surgeons.

Numerous studies have addressed the ergonomic factors that should be considered while designing a surgical instrument for a specific surgical technique.[2,8] These and other studies mainly investigated posture[6,9,10] mental workload,[11-13] pressure distribution,[14,15] and so on. However, the trend has been reversed, and new surgical techniques have arisen or evolved together with the invention of novel instruments and the possibilities that they bring.[16-18] The acceptance of a new surgical instrument within the medical community relies on a great number of factors that are not always objective, and thus, it is challenging to assess them in a holistic way. To the authors' best knowledge, there is no previous work addressing working conditions and subjective preferences of surgeons from different backgrounds in the same study. This article presents an across-surgical-techniques study that attempts to identify the principal factors (background, ergonomics, working conditions, etc) influencing surgical instrument acceptance.

Materials and Methods

A total of 250 surgeons with experience in open, laparoscopic, and robotic procedures were included in this study. Swiss public databases and PubMed were used to gather contact information. Surgeons were contacted with an e-mail explaining the aim of the study, including a link to the anonymous survey with instructions and a general password.

The survey was conducted using a Web-based form. It begins with a short introduction to the purpose of the study and clear directions for completing the questionnaire. Additional instructions throughout the survey were included with the respective questions (eg, "Multiple selection is allowed" or "Give a score from 1 to 5"). The approximate time required to complete the survey was 10 minutes. The survey was performed online via the *Inform* platform at the Ecole Polytechnique Fédéral de Lausanne (EPFL), Switzerland. Incomplete or incorrectly answered surveys were discarded. The valid answers were then statistically analyzed with Matlab (the Mathworks, USA).

The survey contains 21 questions separated into 4 parts: (1) demographic details, (2) discomfort and procedure duration, (3) evaluation of 7 different handles, and (4) choice of the preferred ones (Table 1).

Discomfort and Procedure Duration

The second part of the questionnaire was related to pain and discomfort suffered during or following surgical procedures. Surgeons gave details of the body parts that suffered any kind of discomfort for each surgical technique. To compare the ergonomic issues associated with open, laparoscopic, and robotic surgery, percentages were calculated for each part of the body and within the group of surgeons who had experience in each surgical technique. As task duration represents an important risk factor for work-related injuries, surgeons provided additional information regarding the average duration of the surgical procedures that they perform. The percentage of surgeons voting for each duration range was calculated for all the surgeons first and then separately for the groups with/without experience in robotic surgery.

Handle Evaluation

The third part of the survey consisted of the evaluation of different surgical instrument handles. Seven pictures of surgical instrument handles were presented, and the surgeons were asked about the ergonomics and usability of the open–close mechanism of each instrument. Having in mind such an action, surgeons had to score each handle in terms of intuitiveness, comfort, precision and stability. The score ranged from 1 to 5 points (1 = *bad*; 5 = *good*). An analysis of variance of 4 × 7 (4 properties × 7 handles) was performed to analyze which of the factors were significant and to determine if there was interaction between handle type and handle property. To find the significant differences between handles for each of the properties (intuitiveness, comfort, precision, and stability), we performed a post hoc test Tukey HSD (honestly significant difference) for multiple comparisons.[19] Thereafter, to detect cross-influences between the different evaluated aspects (intuitiveness, comfort, precision, and stability) a correlation matrix was obtained by means of a Pearson correlation analysis with a critical value of $P = .05$.

A supplementary question asked about the addition of extra features and controls on the surgical instrument handle.

Handle Preference

In the fourth part of the survey, surgeons could choose their preferred instrument(s) and eventually explain the reasons for their choice. Since one of the goals of the present study is to determine which are the most influential aspects (intuitiveness, comfort, precision, and stability) on the surgeon's preference regarding the surgical instrument handles, an automatic stepwise multiple variable linear regression with a critical value of $P = .05$ was performed in Matlab. This method systematically adds or removes terms from a multilinear model basing the decision on their statistical significance in a regression. The method begins with an initial model and then compares the results of adding terms to or removing terms from it. At each step, the P value of an F statistic is computed to test the model with and without a potential term. If there is sufficient evidence to reject the null hypothesis ($P < .05$), the new term is added to the model. Conversely, if there is insufficient evidence to reject the null hypothesis ($P > .05$), the term is not included.

At the end of the form, surgeons had the opportunity to elaborate on their response and give further comments and insights. The complete questionnaire is presented in Table 1.

Table 2. Surgeons' demographic and background characteristics

Gender	43 M, 6 F
Experience (no. of surgeons)	
In open surgery	49
In laparoscopic surgery	45
In robotic surgery	24
Mean age (years)	43 ± 8.36

Results

Respondents' Details

A total of 20.4% of all contacted surgeons completed the survey. A total of 51 surveys were collected, of which 2 were incomplete (4%) and had to be removed from the analysis. Therefore, a total of 49 surveys were retained for analysis. The majority of surgeons were male (88%) with a mean age of 43 ± 8.36 years. All were experienced in open surgery, most in laparoscopy, and about 50% in robotic surgery (Table 2).

The respondents mainly worked in Europe (73%) and the United States (17%), with a predominance of European surgeons and especially of surgeons from Switzerland (35%; Figure 1).

Discomfort and Procedure Duration

During open surgery, the major discomfort is felt in the neck and the back (52.1% both) followed by the shoulders (20.8%). During laparoscopic surgery, the main complaints are about the shoulders (41.9%), followed by the neck (37.2%), the back (34.9%), fingers (30.2%), and wrists (20.9%). Surgeons specialized in robotic surgery mostly complained about neck and finger discomfort (28%), followed by the back (20%). None of the surgeons complained about wrist pain while performing robotic surgery, whereas 20.9% complained for laparoscopic and 12.5% for open surgery. For more details, please refer to Figure 2.

In all, 28.5% of the surgeons stated that they normally performed short surgical procedures that do not exceed

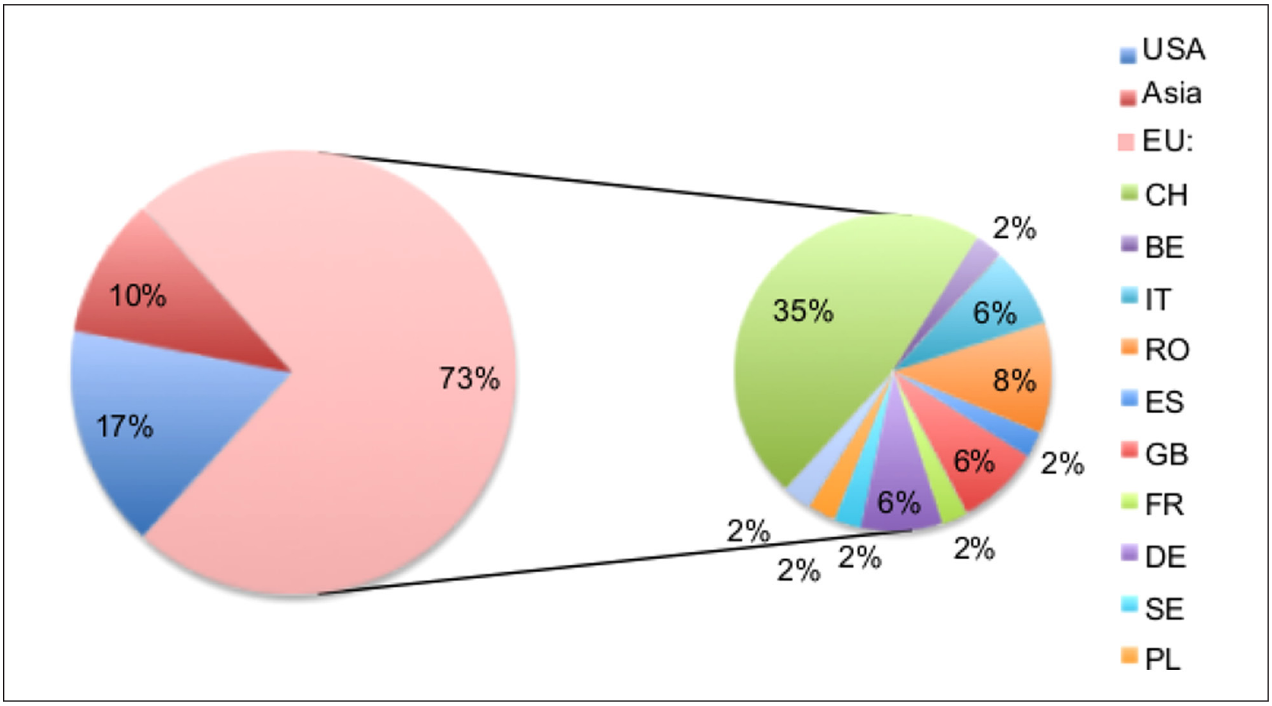

Figure 1. Surgeon's place of work

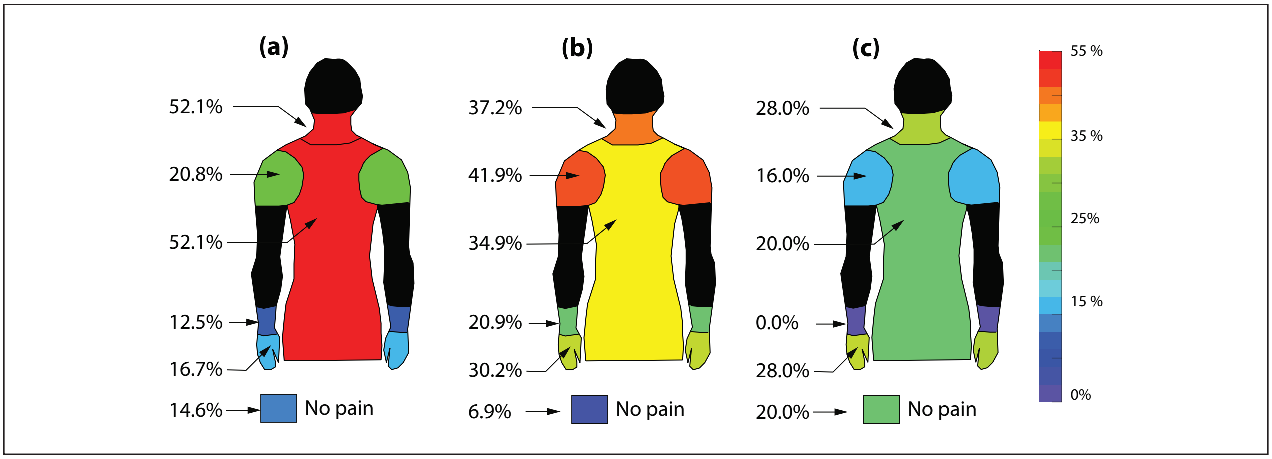

Figure 2. Percentage of surgeons sustaining postoperative pain, numbness, or fatigue in various muscle groups according to type of procedure: A. Open surgery. B. Laparoscopic surgery. C. Robotic surgery

2 hours. The majority (53%) stated that the average duration of the surgical procedure ranges from 2 to 5 hours, and only 18.4% indicated performing operations that last more than 5 hours. The majority of specialists in robotic surgery perform interventions that last between 2 and 5 hours, followed by some who perform interventions that last for more than 5 hours; only a few indicated that they perform surgeries lasting less than 2 hours. For nonrobotic procedures, the percentages were the same for both less than 2 hours and from 2 to 5 hours; a minority of operations lasted for more than 5 hours (Table 3).

Handle Evaluation

We performed a repeated-measures ANOVA to determine if there were significant differences in the ranking resulting from the handle type or different handle properties (Table 4).

In terms of intuitiveness, the conventional needle holder for open surgery (H1) and the da Vinci wrist (H2) received scores of 3.79 and 3.75, respectively. The scores of these handles are not significantly different ($P_{\text{H1-H2}}$ = 1.000). However, these scores are significantly higher

Table 3. Average duration of the surgical procedure in total and per background

Procedure Length	<2 Hours	2-5 Hours	>5 Hours
Robotic surgery	6.1%	30.6%	12.2%
Conventional surgery	22.4%	22.4%	6.1%
Total	28.57%	53.06%	18.37%

Table 4. ANOVA 4x7 for Handle type and Handle property ranking

Effects	*F* Value	*P* Value
Handle type	3318.84	**.000**
Handle property	7.808	**.001**
Interaction: Handle Type × Handle Property	2.985	**.000**

Note: The critical value for significance is p<.05.

Table 5. P values resulting from the Tukey HSD test for intuitiveness scores

Intuitiveness Score	H1	H2	H3	H4	H5	H6
H1 (3.80)						
H2 (3.76)	1.000					
H3 (3.22)	**0.004**	**0.016**				
H4 (3.18)	**0.001**	**0.004**	1.000			
H5 (3.49)	0.862	0.969	0.969	0.862		
H6 (3.49)	0.862	0.969	0.969	0.862	1.000	
H7 (2.94)	**0.000**	**0.000**	0.929	0.989	**0.009**	**0.009**

Note: The p-values in bold indicate significant difference between scores.
Maximum and minimum scores are highlighted.

Table 6. P values resulting from the Tukey HSD test for comfort scores

Comfort score	H1	H2	H3	H4	H5	H6
H1 (3.47)						
H2 (3.53)	1.000					
H3 (3.57)	1.000	1.000				
H4 (2.88)	**0.002**	**0.000**	**0.000**			
H5 (2.90)	**0.004**	**0.000**	**0.000**	1.000		
H6 (3.16)	0.862	0.523	0.290	0.929	0.969	
H7 (3.08)	0.400	0.131	0.050	0.999	0.999	1.000

Note: The p-values in bold indicate significant difference between scores.
Maximum and minimum scores are highlighted.

than the ones obtained by H7, H4, and H3, which were found to be the least intuitive handles. No significant differences were found between them ($P_{H3\text{-}H4}$ = 1.000, $P_{H3\text{-}H7}$ = 0.929, and $P_{H4\text{-}H7}$ = 0.989; Table 5).

Table 7. P values resulting from the Tukey HSD test for precision scores

Precision Score	H1	H2	H3	H4	H5	H6
H1 (3.84)						
H2 (3.90)	1.000					
H3 (3.29)	**0.008**	**0.001**				
H4 (3.06)	**0.000**	**0.000**	0.996			
H5 (2.98)	**0.000**	**0.000**	0.862	1.000		
H6 (3.39)	0.131	**0.029**	1.000	0.767	0.290	
H7 (3.02)	**0.000**	**0.000**	0.969	1.000	1.000	0.523

Note: The p-values in bold indicate significant difference between scores.
Maximum and minimum scores are highlighted.

Table 8. P values resulting from the Tukey HSD test for stability scores

Stability score	H1	H2	H3	H4	H5	H6
H1 (3.67)						
H2 (3.81)	0.996					
H3 (3.55)	1.000	0.969				
H4 (2.91)	**0.000**	**0.000**	**0.000**			
H5 (3.20)	0.083	**0.001**	0.065	0.929		
H6 (3.26)	0.029	**0.008**	0.929	0.650	1.000	
H7 (3.06)	**0.001**	**0.000**	0.051	0.999	0.999	0.999

Note: The p-values in bold indicate significant difference between scores.
Maximum and minimum scores are highlighted.

Regarding comfort, H3 received a score of 3.57, H2 a score of 3.53, and H1 a score of 3.47; differences between these 3 scores are not significant ($P_{H1\text{-}H2}$ = 1.00; $P_{H2\text{-}H3}$ = 1.00; and $P_{H1\text{-}H3}$ = 1.00), but all these scores are significantly higher than those for the pistol-like prototype of the Novare (H4) and the axial handle of the RWOLF needle holder (H5), which were 2.88 and 2.90, respectively. The Tukey HSD results show that these handles are not significantly different between them ($P_{H4\text{-}H5}$ = 1.00; Table 6).

The handles providing the most precision while controlling the instrument aperture were found to be H2 and H1 with scores of 3.90 and 3.84, respectively; differences between these scores are not significant ($P_{H1\text{-}H2}$ = 1.00). Significantly lower scores were obtained by H5 (2.98) and H7 (3.02). The Tukey HSD results showed that H5 and H7 were not significantly different ($P_{H5\text{-}H7}$ = 1.00; Table 7).

On the stability aspect, H2 (3.81), H1 (3.67), and H3 (3.55) were found to be the most stable handles; no significant differences were found between them ($P_{H1\text{-}H2}$ = 0.996; $P_{H1\text{-}H3}$ = 1.00; and $P_{H2\text{-}H3}$ = 0.969). Significantly lower scores were obtained by H4 (2.91) and H7 (3.06). The Tukey HSD test did not find any significant difference between them ($P_{H4\text{-}H7}$ = 0.999; Table 8).

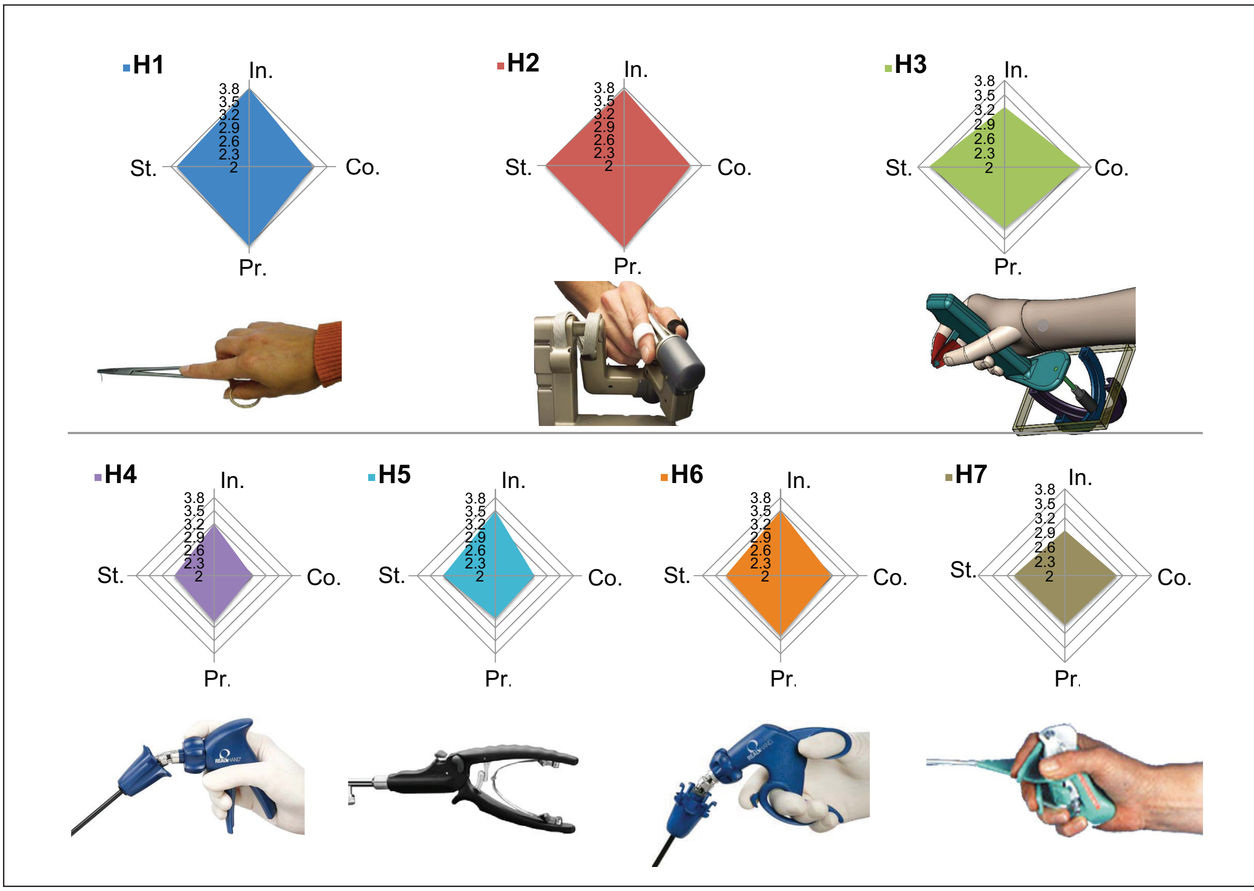

Figure 3. Score for each handle in terms of intuitiveness (In.), comfort (Co.), precision (Pr.) and stability (St.). H1, conventional needle holder; H2, from Intuitive Surgical systems[20]; H3, joystick-like concept proposed by the authors; H4 and H6, from Novare Surgical Systems[21]; H5 from RWOLF[22]; and H7 from Mattern and Weller[23]

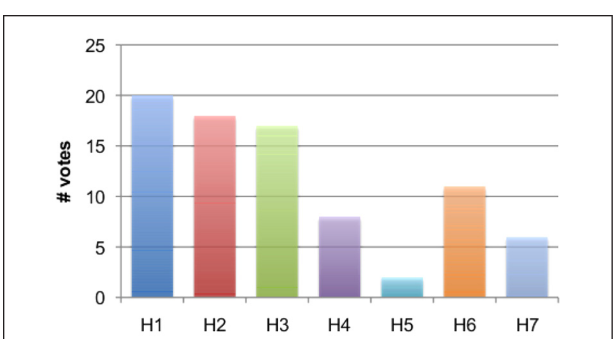

Figure 4. Number of votes per handle; please note that multiple selections were allowed

The correlation matrix showed that there is a significant correlation between the scores given to comfort and stability aspects (Pearson correlation coefficient = 0.92; P = .0032). In addition, the correlation obtained between intuitiveness and precision demonstrates that these 2 aspects are correlated as well (Pearson correlation coefficient = 0.83, P = .02).

Regarding the addition of extra features and controls on the surgical instrument handle, 73.5% of the surgeons reported that they would not like to have any other button or control on it; 24.5% reported that it could be useful to have the control of the ablation tool (eg, to activate the cauterization or to replace pedals) integrated into the handle. Figure 3 summarizes the average of all surgeons' scores for each handle.

Table 9. Correlation matrix between the four handle properties and the preference score

	Preference
Intuitiveness	0.554 (P = .192)
Comfort	0.920 (P = **.003**)
Precision	0.878 (P = **.008**)
Stability	0.842 (P = **.018**)

Handle Preferences

After completing the handle evaluation, surgeons voted for their preferred handle(s) to control the instrument aperture (please note that multiple selections were allowed). H1, H2, and H3 were the preferred handles because they

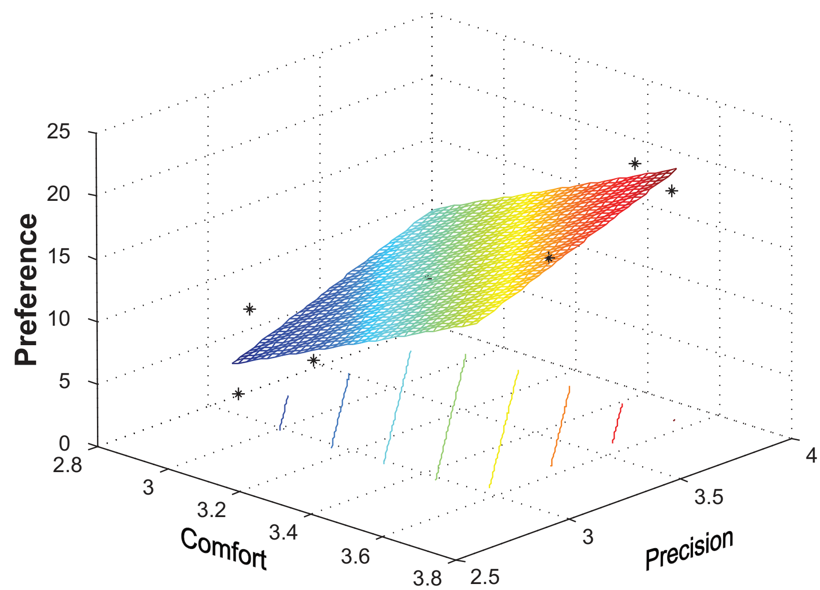

Figure 5. Resulting regression model and survey results: handle preference as a function of comfort and precision

obtained a significantly higher number of votes (Figure 4). Thereafter, a stepwise regression analysis was performed to obtain the model that best represented the choice pattern of surgeons for surgical instrument handles.

According to the correlation matrix between preference scores and the 4 handle properties shown in Table 9, preference is not correlated with intuitiveness but shows a high correlation with the other 3 properties. However, as reported in the previous section, there is a correlation between intuitiveness and precision as well as between comfort and stability. Therefore, the stepwise regression analysis showed that a model including the 3 aspects overfitted the preference function and was thus not valid. The model that best represented the handle preference pattern of the surgeons was found to be a function of comfort (c) and precision (p); $R^2 = 0.911$, $P = .007$.

$$\mathrm{Hp}\,(c, p) = -57.22 + 13.80\cdot\mathrm{comfort} + 7.27\cdot\mathrm{precision}. \quad (1)$$

Figure 5 shows the preference model represented as a plane with respect to comfort and precision. As can be deduced from Equation (1) and from the slope in Figure 5, comfort has more influence on handle preference than precision.

Significant differences ($P < .001$) were found in handle preferences between the 2 sets of data grouped according to their experience with robotic surgical systems (experience/no experience; Figure 6)

The highest score was given to the handles with which the surgeons were more familiar: the conventional needle holder (H1) for surgeons used to conventional surgery and the da Vinci wrist for surgeons specialized in robotic surgery (H2).

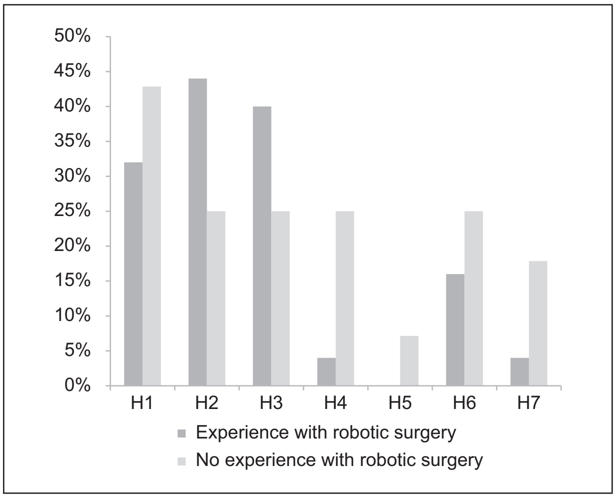

Figure 6. Percentage of surgeons in each group who voted for each handle, grouped by background with and without experience in robotic surgery

Discussion

Minimally invasive surgical procedures, especially laparoscopy, require the surgeon to adapt nonneutral back postures and raised shoulder positions, producing higher muscular loading when compared with open surgery[9] and robotic surgery.[6,10] This fact has been confirmed by our results regarding the discomfort and pain areas suffered during each surgical approach. As has been shown, there is a clear decrease of aftereffects for robotic surgery. Nevertheless, we noted that a significant number of surgeons complained about neck and finger pain during robotic surgery. Previous studies reported that surgeons already complain about neck pain because of the static posture they have to adopt to keep their eyes aligned to the 3D monitor.[6,24] However, there has been no evidence to date of surgeons' discomfort regarding the surgical console handle. The da Vinci handle (H2) allows the surgeons to control the surgical instrument with only 2 fingers. The hand posture utilized with this handle is the precision grasp naturally used by humans for fine manipulation; but even though it allows fine control, for manipulations requiring repetitive and large movements, it might induce additional muscular tension. Nevertheless, the improvement felt by the surgeons with respect to wrist and shoulder pain is incontestable.

Task duration represents an important risk factor because it plays a significant role in the development and onset of musculoskeletal injuries; longer procedure duration will definitely increase the risk of adverse effects produced by a poor ergonomic design. Judging from the surgeons' answers, it seems that the majority of the procedures performed with a robotic surgical platform last more than 2 hours, whereas with other techniques, the same percentage was obtained for durations of less than 2 hours and from 2 to 5 hours. Similar results were found in other studies comparing operative times for a common cholecystectomy performed laparoscopically and with the robot. These studies showed that robotic surgery took more time because of the sterile draping required[25] or because of the slow motion of the robot's arms.[26] However, in the study by Lawson et al,[6] the operative times to perform a Roux-e-Y gastric bypass laparoscopically were longer compared to that using a surgical robot. The variation in the reported results suggests that the difference in operating times significantly depends on the surgical procedure. It might be advantageous in terms of operation time to use the robot in complicated procedures, which are typically long, whereas for simple procedures, the extra time to set up the device dominates the duration of the surgical procedure. Nevertheless, it should be highlighted that even though on average robotic surgeries last longer; the reported discomfort suffered by the surgeons was significantly lower.

Concerning the handle evaluation, a strong correlation was found between the scores given for comfort and stability aspects and also between those for intuitiveness and precision.

According to the classification proposed by Napier,[27] 3 of the handles (H1, H2, and H6) are controlled by a precision grip (tool held between the tip of the thumb and the opposing digits). For handle H5, the aperture can be controlled by a pure power grip (grip between all fingers and palm with the thumb adducted at both the metacarpophalangeal and carpophalangeal joints); for H4, the thumb is adducted to increase grip power. Handles H3 and H7 require a combined grip. For H3, the aperture is controlled by the thumb and index finger in a precision grip posture while the remaining fingers are in a power grip. In the case of H7, the handle is controlled by independent movement of the index and annular fingers and held by the thumb and the rest of the fingers in a power grip. We noticed that handles requiring the surgeon to use a power grip to control surgical instrument aperture received low precision scores (H4 and H5). The handles in which the instrument aperture was controlled by a precision grip that only used the index finger and thumb obtained the highest scores for both comfort and stability (H1, H2, and H3). Regarding the shapes of the handles, it was found that the pistol-shaped and joystick-shaped handles, which need to be grasped with the whole hand, were less intuitive (H4, H3, and H7).

With the intention of discovering the most important underlying aspects that support the surgeons' preference criteria, the correlation between the handle preference ranking and these aspects was obtained. This suggests that surgeons chose the handle mainly based on the comfort aspect and to a lower degree because of the precision they provide. We appreciate the argument that the aspects that surgeons scored in this survey are subjective and multidimensional in nature, and therefore, several other variables might be necessary to adequately represent this theoretical preference model. However, the objective of this research is not to test theoretical models but to understand the choice behavior of surgeons to design the devices that better meet their needs.

The background of the surgeon was found to be a significant factor in handle preference. For both groups, the preferred choice was the handle with which they were more familiar. Generally, those surgeons with robotic experience preferred the da Vinci handle, whereas those with no experience in robotic surgery preferred the conventional needle holder used for open surgery. This hypothesis is supported as well by the additional comments given by several respondents who suggested that their choice was based on their previous experience (eg, "because I'm used to," "experienced with these devices," "habits," etc). Therefore, the design of new instruments should take into account the instruments already used in that specific field or in daily life. Totally unknown instruments whose control must be relearned will alter the surgeon's clinical practice.

This study also presents a number of limitations that must be discussed: in our opinion, the major factors that have to be taken into consideration when interpreting the survey results are the Internet-related aspects of the survey and the high proportion of responses from surgeons experienced in robotic surgery. To compare surgeons' preferences with respect to their background, we sought to have a similar numbers of surgeons performing robotic surgery and surgeons who never performed it. However, nowadays. the number of surgeons performing robotic surgery does not represent 50% of the total (only about 3450 surgeons are officially registered in the Intuitive Surgical database[20]). Furthermore, the median age in our study is 43 years, reflecting the fact that the younger surgeons tend to use computers and the Internet on a daily basis and are most probably more familiar with this type of media than older surgeons. We therefore acknowledge an age-selection bias, the consequence of which is that our results concern mostly a younger population of surgeons roughly 30 to 55 years of age and thus more acquainted with new surgical trends and instruments. Although a more extensive study should evaluate our results in the remaining population, we consider these results as a first appreciation of a population who will certainly have, as a result of their background, a high degree of concern about new surgical technologies and thus will represent the preferences of potential users. Another limitation that should be considered is that surgeons evaluated the handles purely based on the pictures provided and thus had more information about the handles if they had previously used them. This issue might have influenced the result that relates handle preference to surgeons' experience. A survey allowing surgeons to try the real instruments would give more detailed insights into this issue.

Conclusions

The current study strongly supports the hypothesis that there are significant ergonomic problems related to surgical techniques that result in frequent physical discomfort for a substantial number of practicing surgeons. According to the surgeons' responses, the arm support brought by the master console of robotic surgery systems significantly alleviates wrist and shoulder pain typically found in traditional surgery. Nevertheless, further improvements in the surgeon's posture while seated at the master console and in the handle of the robotic surgery instruments should be made to decrease the likelihood of work-related physical injuries.

The results of handle comparison suggest that surgeons' choice is mainly driven by 2 factors: comfort and precision. Handles that control the instrument aperture with a power grip posture were associated with low precision. Handles in which the control is performed with only 2 fingers (combined power and precision grip) were preferred in terms of comfort. In addition, it has been found that handle preference is strongly correlated with surgeons' background. Therefore, surgical instrument designers should first study the tools already used in that specific field or in day-to-day life to guarantee the acceptance of new instruments.

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