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Port placement and patient-specific docking strategies for robotic hysterectomy with the Hugo™ RAS system: an international Delphi consensus

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ABSTRACT

Background: Robotic-assisted hysterectomy is increasingly performed using modular platforms such as the Hugo™ robotic-assisted surgery (RAS) system, but optimal or personalised docking strategies remain undefined.

Objectives: To establish expert consensus on port placement and docking configurations for hysterectomy with the Hugo™ RAS system and to identify patient anthropometric factors requiring modification of standard setups.

Methods: A modified Delphi consensus was conducted involving two iterative rounds of anonymous, structured questionnaires distributed to an international panel of gynaecological robotic surgeons experienced with the Hugo™ RAS system. Survey items addressed preferred docking configurations, the influence of patient anthropometry on docking strategy, and specific technical adjustments in non-standard scenarios. Consensus was predefined as ≥66.7% agreement.

Main Outcome Measures: Expert agreement on docking setups, port placement modifications, and anthropometric variables influencing technical adjustments.

Results: Seventeen experts completed round one and 16 completed round two. No single docking configuration reached consensus as universally optimal for standard hysterectomy. Ranking exercises identified the "standard" hysterectomy setup as the most preferred configuration, followed by the "alternate" and the "three-arm" setups. All experts agreed that patient anthropometry requires modification of port placement. Elevated body mass index (BMI), large uterine size and small pelvis were identified as key variables: increasing inter-port distance was recommended for BMI >30, cranial port displacement for large uteri, while no consensus emerged for patients with a small pelvis. A modified bridge configuration was proposed, and achieved strong expert agreement.

Conclusions: No single docking configuration is deemed to be universally optimal for Hugo™ RAS hysterectomy. Expert practice combines a limited number of preferred setups with patient-tailored adjustments.

What is New? This study provides the first Delphi-based expert consensus on Hugo™ RAS docking strategies, emphasizing patient-specific adjustments and flexible preoperative planning.

Keywords: Body mass index, Delphi consensus, robotic-assisted surgery, robotic hysterectomy

Introduction

Hysterectomy is one of the most frequently performed surgical procedures in women,[1] and over recent decades the proportion performed using minimally invasive approaches has steadily increased.[2] The introduction and diffusion of robotic platforms from 2005 onward further reshaped surgical practice patterns;[3,4] within three years of robotic platform adoption at institutions offering robotic hysterectomy, robotic procedures accounted for more than one-fifth of all hysterectomies performed.[5]

The rapid expansion of this market has stimulated several competitors to develop new robotic platforms, introducing technological innovations and distinct designs.[4,6] In 2022, the Hugo robotic-assisted surgery (RAS) system (Medtronic, Dublin, Ireland), was approved for clinical use and many different medical specialties adopted it in their practice.[7-11] Unlike boom-based platforms, the system is characterised by four independent robotic arm carts that can be positioned individually within the operating room. This modular architecture offers substantial flexibility and the potential to tailor docking strategies to specific pathologies, and patient characteristics, and is now used for a wide range of gynaecological procedures.[12] At the same time, it introduces additional complexity into preoperative planning, increasing the number of variables that must be considered to allow for optimal port placement.

Preclinical dry-lab and cadaveric studies have proposed several standardised port placement and docking configurations for gynaecological procedures, with the aim of standardising a number of robotic setups capable of reliably completing the planned operation.[13]

These studies have demonstrated technical feasibility and reproducibility under controlled conditions; however, they have generally not accounted for the wide anthropometric and anatomic variability encountered in routine clinical practice. Moreover, data describing how surgeons adapt these configurations in real-world settings are sparse, and no consensus currently exists regarding which setups are most commonly employed or how docking strategies should be modified in response to patient-specific factors.

In the absence of robust comparative clinical data, structured expert consensus represents a valuable method to synthesise collective experience and guide early adoption of emerging surgical technologies. The objective of the present study was therefore to establish expert consensus on port placement and docking configurations for hysterectomies performed with the

Hugo RAS system and to identify patient anthropometric variables that necessitate deviation from standard setups and to characterise the specific technical adjustments experts apply in these scenarios.

Methods

Study Design and Expert Panel Selection

This consensus statement was developed using a modified Delphi methodology organised by the European Society for Gynaecological Endoscopy (ESGE), Robotic Surgery Special Interest Group. The study was approved by the ESGE Academy Faculty before initiation and was reviewed after completion by the same Faculty. The Delphi approach was selected as an appropriate method to address areas of clinical uncertainty in which high-quality comparative data are lacking and expert experience plays a central role in informing best practice.[14-16] The study consisted of two iterative rounds of structured, anonymous questionnaires administered via email through a secure web-based platform (Jotform®, San Francisco, CA, USA).

Participants were selected based on predefined expertise criteria. Eligible experts were board-certified gynaecological surgeons with substantial experience in RAS and direct clinical familiarity with the Hugo RAS system. Additional inclusion criteria included a high annual robotic case volume and active involvement in robotic surgery programmes and education. Experts from multiple countries and practice settings were invited to ensure broad representation of clinical perspectives.

Delphi Rounds and Questionnaire Structure

Both Delphi rounds included Likert-scale and multiple-choice questions. An open-ended free-text field was included at the end of each section to allow participants to provide additional comments, propose alternative docking configurations, or identify relevant variables not captured by predefined response options.

The first round aimed to collect general information about the participants and their routine clinical practice and was divided into two sections. Section 1 focused on port, cart, and assistant placement for a standard hysterectomy, defined as a procedure in which the uterus, cervix, and, if indicated, adnexa are removed while preserving surrounding structures, performed on a patient with normal anatomy using a routine surgical approach without modifications. Questions 1-3 addressed general aspects of the procedure, including the preferred number of robotic arms, optimal assistant positioning, and cart placement within the operating room. Questions 4-9 focused on commonly used docking setups; schematic images of these configurations were provided to evaluate agreement with setups described in the literature and user manuals, to collect data on those most frequently used in clinical practice, and to identify any considered suboptimal (Figure 1).

Section 2 addressed non-standard hysterectomies, defined as procedures deviating from the standard due to atypical patient anthropometric characteristics or increased anatomical complexity that may interfere with the usual docking strategy, requiring modifications to optimise instrument positioning and facilitate access to the anatomy of interest. Questions 1-2 explored whether individual patient characteristics influence docking and cart placement in general, while questions 3-8 evaluated specific anthropometric variables, assessing whether they necessitate modifications to docking configuration and/or cart positioning. At the end of both sections, participants were given the opportunity to suggest additional setups or variables to be considered in the second round.

In the second round, the focus was (1) to evaluate the different port placement setups and anthropometric variables newly proposed by participants in the first round and (2) to further explore the variables that reached consensus in round 1, with the aim of understanding the technical adjustments and docking strategies applied in these situations to ensure an effective and safe surgical setup. Questions 1-4 focused on refining consensus regarding docking setups. The first question asked participants to subjectively rank the setups identified in the first round in order of preference on a five-point scale (1: most preferred; 5: least preferred), as none had reached the predefined consensus threshold. The subsequent three questions evaluated the docking setups newly proposed by participants. Questions 5-14 addressed the technical adjustments required for docking in the presence of anthropometric variables that had reached consensus in the previous round. For each variable, experts were allowed to select more than one adjustment and were also given the opportunity to describe any docking configurations routinely adopted in their clinical practice for these specific patient scenarios. Finally, Questions 15-18 evaluated the additional anthropometric variables proposed by participants during the first round, assessing their perceived relevance for modifying docking and setup strategies.

Two Delphi rounds were considered sufficient based on achievement of consensus in key domains and diminishing emergence of novel themes after the first iteration.

Data Analysis

Responses were summarised using descriptive statistics and reported as number and percentage of respondents[n (%) or n/N (%)]. Consensus was defined a priori as agreement by at least 66.7% of participants, corresponding to a score of 4 or 5 ("agree" or "strongly agree") on five-point Likert-scale items or concordant selection of the same option in multiple-choice questions. Although there is no standard threshold,[16] this one has been widely applied in prior Delphi-based consensus studies and was selected to balance stringency with feasibility in a specialised expert population.[15-17]

Free-text responses were reviewed qualitatively and used to inform questionnaire refinement and item generation for the second Delphi round.

Statistical analyses were performed using R software (version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria).

Results

Expert Panel Characteristics

Of the 22 experts invited to participate, 17 agreed to take part in the first Delphi round, corresponding to a response rate of 77%. Participants represented seven countries and were predominantly male (12/17, 71%). The median age was 50 years [interquartile range (IQR) 43–55], with a median of 20 years (IQR 14–25) of overall clinical practice and 5 years (IQR 2–8.5) of robotic surgery experience.

Most participants reported a high robotic case volume, with 10 of 17 experts (59%) performing more than 50 robotic procedures annually. All panellists had direct clinical experience with the Hugo RAS platform. In addition, 13 participants (76%) routinely used the da Vinci system (Intuitive Surgical, Sunnyvale, USA), and 6 (35%) reported experience with the Versius platform (CMR Surgical, Cambridge, UK). The majority of experts (14/17, 82%) practiced in university or academic hospital settings. These results are summarised in Table 1.

Round 1 Results

The level of agreement among experts regarding docking configurations for standard hysterectomy is summarised

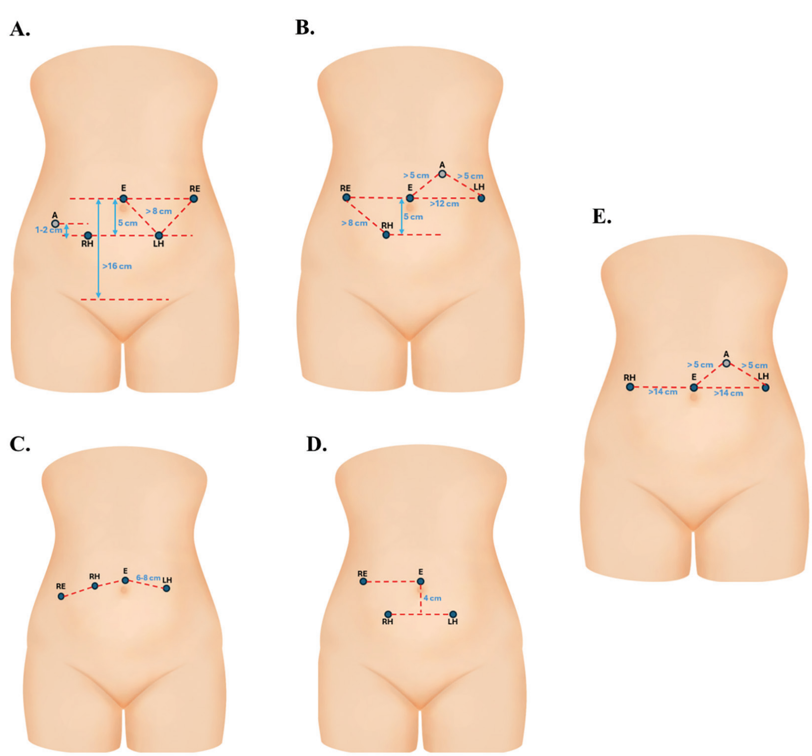

Figure 1. The 5 setups described in the user manual and in literature that were shown to the participants (A: "Standard" setup; B: "Alternate" setup; C: "Straight" setup; D: "Bridge" setup; E: "3-arm" setup).

E: Endoscope, RH: Surgeon right hand, LH; Surgeon left hand, RE: Reserve arm, A: Assistant.

in Table 2. No configuration reached the predefined consensus threshold.

The highest levels of agreement were observed for the assistant positioned at Palmer's point and the compact cart configuration, each endorsed by 11 of 17 experts (64.7%), followed by the straight hysterectomy setup, receiving agreement from 9 experts (52.9%).

All participants (17/17, 100%) agreed that patient anthropometric variables require modification of port placement strategies. In contrast, a smaller proportion of experts (12/17, 70.6%) indicated that cart placement also requires adjustment based on patient characteristics.

Among predefined anthropometric factors, body mass index (BMI) >30 (14/17, 82.4%), large uterus (16/17, 94.1%), and small pelvis (14/17, 82.4%) reached consensus as variables necessitating modification of standard port placement strategies. In contrast, xipho-pubic distance (7/17, 41.2%) and large pelvis (10/17, 58.8%) did not reach consensus.

During the first round, experts proposed three additional docking configurations for further evaluation: a modified hysterectomy alternate setup with the assistant positioned in the iliac fossa, a modified three-arm configuration, and a modified bridge setup (Figure 2). In addition, four anthropometric variables not included in the initial questionnaire were suggested for consideration in subsequent rounds: short umbilico–pubic distance, history of major abdominal surgery, abdominal hernia, and pelvic organ prolapse.

Table 1. Expert panel characteristics.

Country of residence	9: Italy 3: Denmark 1: Portugal 1: India 1: Spain 1 Australia 1: UK
Age	50 [43-55]
Years of experience as a gynaecological surgeon	20 [14-25]
Gender	12: male; 5: female
Years of experience in robotic surgery	5 [2–8.5]
Number of robotic procedures per year	7: <50; 6: 50 to 100; 4≥100
What robotic system have you used?	17: Hugo RAS; 13: DaVinci (Si, Xi, X, SP); 6: Versius; 1: other
In what type of hospital do you work?	12: university hospital; 2: both university and private; 1: community hospital; 1: private clinic; 1: other

RAS: Robotic-assisted surgery.

Table 2. Expert agreement on docking setups and anthropometric considerations during hysterectomy (Round 1).

Domain	Item	Agreement (n)	Agreement (%)
Docking setups	Assistant at Palmer's point	11/17	64.7%
	Compact cart configuration	11/17	64.7%
	Standard hysterectomy setup	4/17	23.5%
	Alternate hysterectomy setup	7/17	41.2%
	Three-arm hysterectomy setup	7/17	41.2%
	Bridge hysterectomy setup	6/17	35.3%
	Straight hysterectomy setup	9/17	52.9%
Anthropometric impact	Anthropometric variables require port placement modification	17/17	100%
	Anthropometric variables require cart placement modification	12/17	70%
Anthropometric variables	BMI	14/17	82.4%
	Large uterus	16/17	94.1%
	Small pelvis	14/17	82.4%
	Xifopubic distance	7/17	41.2%
	Large pelvis	10/17	58.8%

BMI: Body mass index.

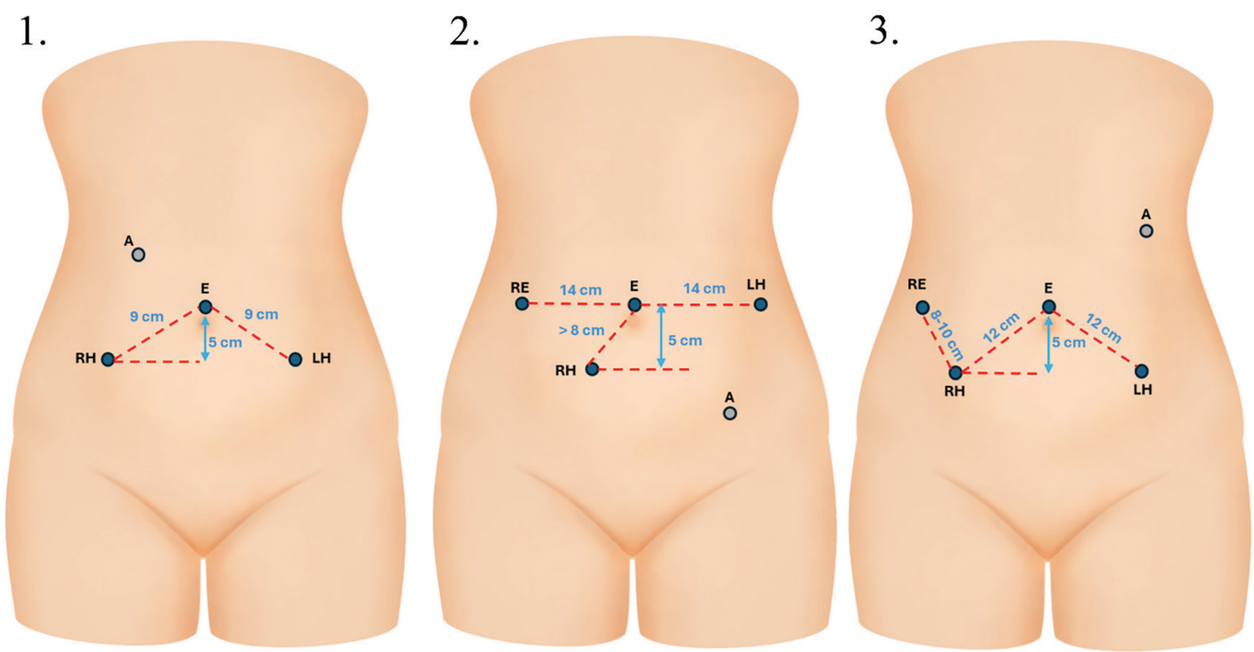

Figure 2. The 3 setups that were proposed in round 1 and then evaluated in round 2 by the participants (1: Modified 3-arm; 2: Alternate with assistant in iliac fossa; 3: Modified bridge).

E: Endoscope, RH: Surgeon right hand, LH; Surgeon left hand, RE: Reserve arm, A: Assistant.

Round 2 Results

Sixteen experts completed the second Delphi round.

Experts were asked to rank five hysterectomy docking configurations in order of preference on a five-point scale (1: most preferred; 5: least preferred). The standard hysterectomy setup was ranked as the most preferred configuration, with the lowest mean ranking score (2.25), indicating greater overall preference. This was followed by the alternate setup (2.62) and the three-arm configuration (2.87). The bridge (3.62) and straight (3.65) setups received the highest mean scores, reflecting lower relative preference (Table 3). Expert agreement regarding technical adjustments applied in the presence of anthropometric variables that reached consensus is summarised in Table 4. For practical applicability, a summary of expert-recommended docking adjustments according to anthropometric variables is provided in Table 5.

For patients with BMI >30, increasing the distance between ports was the only adjustment to reach the predefined consensus threshold (11/16, 68.7%). Other strategies, including the use of four robotic arms (4/16, 25%), three arms (2/16, 12.5%), cranial displacement of ports (3/16, 18.7%), or optical displacement (3/16, 18.7%), did not reach consensus.

In cases of large uterus, cranial displacement of ports reached consensus (11/16, 68.7%). Optical displacement was frequently selected (9/16, 56.2%) but did not meet the consensus threshold. The use of four robotic arms (7/16, 43.7%) and increased inter-port distance (3/16, 18.7%) also failed to reach consensus.

For patients with a small pelvis, no technical adjustment achieved consensus. Moderate levels of agreement were observed for decreased distance between ports (8/16, 50%) and the use of a three-arm configuration (9/16, 56.2%), whereas other strategies were infrequently endorsed.

Agreement levels for additional anthropometric variables and docking configurations proposed during the first

Table 3. Ranking of hysterectomy docking setups based on expert preference.

Setup	Average position
Standard	**2.25**
Alternate	2.62
3 arms	2.87
Bridge	3.62
Straight	3.65

round are summarised in Table 6. Short umbilico–pubic distance reached consensus (12/16, 75%), as did history of major abdominal surgery (11/16, 68.7%). Abdominal hernia approached but did not reach the consensus threshold (10/16, 62.5%), whereas pelvic organ prolapse received low agreement (3/16, 18.7%).

The modified bridge setup achieved the highest level of agreement, with 15 of 16 experts (93.7%) supporting its consideration. The modified three-arm configuration reached consensus (11/16, 68.7%). In contrast, the alternate setup with the assistant positioned in the iliac fossa did not reach consensus (5/16, 31.2%).

Discussion

This Delphi study provides the first structured synthesis of expert opinion on docking configurations and port placement strategies for hysterectomy performed with the Hugo RAS system. In the context of limited platform-specific clinical literature, these findings offer clinical guidance that reflect real-world experience across

Table 4. Expert agreement on technical adjustments for key anthropometric variables during hysterectomy.

Anthropometric variable	Adjustment/Consideration	Agreement (n)	Agreement %
BMI >30	Increase distance between ports	11/16	68.7%
	Use of 4 arms	4/16	25%
	Use of 3 arms	2/16	12.5%
	Cranial displacement	3/16	18.75%
	Optical displacement	3/16	18.75%
Large uterus	Cranial displacement	11/16	68.7%
	Use of 4 arms	7/16	43.75%
	Use of 3 arms	1/16	6.25%
	Increase distance between ports	3/16	18.75%
	Optical displacement	9/16	56.25%
Small pelvis	Decreased distance	8/16	50%
	3-arm setup	9/16	56%
	Different assistant position	2/16	12.5%
	Optical entry point lower	1/16	6.25%

BMI: Body mass index.

Table 5. Summary of expert-recommended docking adjustments according to anthropometric variables in Hugo RAS hysterectomy.

Anthropometric variable	Preferred adjustment
BMI >30	Increase inter-port distance
Large uterus	Cranial displacement of ports
Small pelvis	Reduced spacing/3-arm (moderate agreement)

BMI: Body mass index.

Table 6. Expert agreement on additional anthropometric variables and on additional docking approaches.

	Panel proposal	Agreement (n)	% Agreement
Anthropometric variable	Short umbilico–pubic distance	12/16	75%
	History of major surgery	11/16	68.7%
	Abdominal hernia	10/16	62.5%
	Pelvic organ prolapse	3/16	18.7%
Docking setup	Modified 3-arm	11/16	68.7%
	Modified bridge	15/16	93.7%
	Alternate with assistant in iliac fossa	5/16	31.25%

different practice settings. The consensus indicates that expert-driven innovation contributes to the refinement of surgical techniques during the early phases of platform adoption and points to the limitations of relying solely on preclinical or standardised docking models. In addition, optimal use of the Hugo RAS system requires flexibility and case-specific adaptation, particularly with respect to patient anthropometry.

A key finding of this study is that no single docking setup reached consensus as universally optimal during the first Delphi round, confirming the heterogeneity of current clinical practice. This contrasts with the more standardised port placement paradigms established for earlier robotic platforms, where extensive clinical experience and a less flexible design have facilitated convergence toward a limited number of accepted configurations.[18,19]

The subsequent ranking exercise in round two revealed that, despite this variability, experts consistently favoured a standard hysterectomy setup, followed closely by an alternate and a three-arm configuration. Importantly, these results reflect relative preference rather than formal consensus and should therefore be interpreted as indicative of comparative inclination among experts rather than agreement on an optimal configuration. Notably, these three configurations share the fact that they are described in the system user manual, unlike other setups reported in the literature and their higher ranking may therefore reflect greater familiarity and visibility rather than superiority. As additional strategies are developed and standardised, strategies of disseminations should be adopted to help clinical adoption.

The strongest area of agreement among experts was the need to modify port placement in response to patient anthropometric characteristics.

For patients with elevated BMI, increasing the distance between ports was the only strategy to reach consensus. This observation is consistent with ergonomic and kinematic principles of robotic surgery. In patients with higher BMI, extensive modifications are usually not required; rather, taking advantage of the larger abdominal surface to increase the distance between ports is considered optimal, as it helps minimise robotic arm collisions even in the presence of increased abdominal wall thickness and limited intra-abdominal working space.[20,21]

Large uterine size is a recurrent challenge in minimally invasive surgery,[22,23] and despite new strategies are still emerging to solve this problem,[24] cranial displacement of the ports was the only adjustment reaching consensus. This modification consists in a translation of the ports while preserving the surgeon's preferred setup and for this reason is easy to implement, and it gives the advantage of having an appropriate working distance, enabling the robotic instruments to fully exit the trocars and achieve effective control without excessive proximity to the target anatomy.

For small pelvic anatomy, no single modification reached consensus. The moderate agreement observed for reduced port spacing and three-arm configurations suggests that surgeons may attempt to mitigate instrument crowding by simplifying the setup; however, the absence of consensus underscores a fundamental limitation of robotic surgery, namely the requirement for a minimum working space to ensure smooth and effective operative performance.

Another relevant contribution of this Delphi process was the identification and evaluation of docking configurations that are not prominently addressed in either the published literature or manufacturer guidance. The modified bridge configuration achieved a high level of agreement in the second round, reflecting strong expert support. Conceptually, this configuration may be interpreted as an intermediate solution between the three-arm and the standard four-arm setups, two configurations that were both highly ranked in the second round of this study. By combining elements of these approaches, the modified bridge setup appears to integrate their respective advantages: it allows both primary working arms to be positioned deeper within the pelvis, allowing for a better instrument reach, while maintaining a reserve arm on the dominant-hand side of the surgeon.

Although its geometric layout resembles a classical bridge configuration, a key difference is the incorporation of standardized spacing parameters between ports, potentially enhancing reproducibility across operators. Lastly, the relatively reduced distance between the right arm and the reserve arm may facilitate four-arm docking even in patients with smaller pelvic anatomy.

This finding illustrates how structured expert consensus can generate practical refinements that extend beyond preclinical testing, and how the progressive description and dissemination of new setups may contribute to further optimisation of surgical practice.[25-28]

From an educational perspective, the findings of this study support the incorporation of flexible docking strategies into robotic training curricula and simulation programmes.

Future research should focus on objective evaluation of docking configurations in relation to operative time, collision frequency and surgeon ergonomics to further validate the recommendations presented here.

Strengths and Limitations

A major strength of this study is the use of a structured, iterative modified Delphi methodology with predefined consensus thresholds. This approach is particularly well suited to the early evaluation of emerging surgical technologies, allowing for a systematic analysis of clinical experience. The inclusion of internationally recognised experts with direct clinical experience using the Hugo RAS system further enhances the relevance and credibility of the findings.

Several limitations should also be acknowledged. As with all Delphi-based studies, the findings reflect expert opinion rather than objective data and therefore should only be interpreted as guidance. However, in the context of a novel robotic platform with limited clinical literature, expert consensus represents an essential and widely accepted step in guiding safe adoption and informing subsequent hypothesis-driven research. Although the expert panel was international and highly experienced, the sample size was necessarily limited by the relatively small pool of surgeons with substantial hands-on experience with the platform.

Lastly, ongoing technological refinements to robotic platforms may change docking principles in the future, potentially impacting the longevity of specific recommendations. Still, the principles identified in this consensus, such as the need for flexible, patient-centred port placement strategies and adaptation to anthropometric variability, are likely to remain applicable even as hardware evolves.

Conclusion

This expert consensus demonstrates that no single docking configuration is universally optimal for hysterectomy performed with the Hugo RAS system. Rather, contemporary expert practice is defined by selective use of a limited number of preferred port placement setups, combined with deliberate modification in response to patient-specific anthropometric factors, such as elevated BMI, large uterine size, and small pelvis. These findings confirm the importance of flexibility and individualised preoperative planning when using a modular robotic platform.

Future research should focus on prospective clinical and simulation-based studies to validate and refine patient- and procedure-specific port placement strategies.

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Ethical approval: Given the design of the study (expert consensus), ethical approval was not required.

Informed consent: Given the design of the study, informed consent was not required.

Data sharing: The data that support the findings of this Delphi consensus are available upon reasonable request from the corresponding author.

Transparency: Hereby, I affirm (as corresponding author) that this manuscript is an honest, accurate, and transparent account of the study being reported. No important aspects of the study have been omitted. Discrepancies from the study as planned have been explained.

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