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The RoboDev Guideline: Key Requirements and Recommendations for Developing and Expanding Global Robotic Surgical Programmes

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Abstract

Background: Robot-assisted surgery (RAS) is expanding rapidly across surgical specialities, yet adoption across the globe remains variable. There is growing recognition to expand RAS across all healthcare settings, to ensure equity of access and improve clinical outcomes for all patients. Facilitating the expansion of RAS requires the development of high-quality, durable and sustainable RAS programmes. The aim of the RoboDev study was to develop a universal, globally applicable guideline to aid development and expansion of RAS programmes.

Methods: The RoboDev study was conducted as an international, multistakeholder Delphi process consisting of four phases: (1) scoping review and item generation, (2) questionnaire design and pre-testing, (3) accelerated two-round Delphi survey, and (4) consensus meetings. Participants were stratified by World Bank income classification. Recommendations achieving ≥80% agreement were retained. A subset of participants subsequently evaluated the final recommendations using the APEASE criteria (Acceptability, Practicability, Effectiveness, Affordability, Spill-over effects, and Equity).

Results: A total of 1,000 participants completed Round 1 and 812 completed Round 2 of the Delphi, representing HIC (59.5%), UMIC (16.6%), LMIC (18.7%), and LIC (1.6%) stakeholders. From 245 initial statements across eight domains, 194 recommendations achieved global consensus. Tailored adaptations were added for each income group, resulting in 197 recommendations for HICs, 207 for UMICs, 206 for LMICs, and 216 for LICs. Training, infrastructure readiness, and multidisciplinary engagement showed the greatest variation across settings. APEASE evaluation confirmed overall acceptability, practicality, and equity, with LIC participants reporting the highest spill-over and equity benefits.

Conclusion: The RoboDev study has developed the first global, evidence-based, and context-sensitive guidelines for building and expanding robot-assisted surgical programmes. By combining universal principles with context-specific adaptations, these recommendations provide a roadmap for equitable and sustainable expansion of robotic surgery worldwide. Adoption of these guidelines has the potential to improve patient outcomes, strengthen surgical systems and ensure that the benefits of robotic innovation are shared equitably across all global contexts.

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Background

The adoption of robot-assisted surgery (RAS) continues to expand owing to the universal recognition of its potential clinical benefits across a range of surgical specialities[1-4]. Consequently, the robotic marketplace continues to grow at pace, with an annual growth rate of 16.5%[5]. Over 10 million robotic procedures have

been performed worldwide across 7733 installed robotic systems[6]. Despite the upward trajectory, adoption of robot-assisted surgery is uneven across the globe, with estimates suggesting 2% of surgeries in Europe and 15% in the USA are performed robotically. The penetrance in low- and middle-income settings (LMICs) is unknown, however, is likely negligible. Despite this, the robotic landscape in LMICs is growing, with the development of contextually relevant, innovative and cost-effective robotic programmes, as well as the early adoption and evaluation of new robotic systems[7].

Globally, there is recognition of the need to strengthen the evidence base for RAS across all specialities and settings. Delivering this evidence requires efficient, effective, and sustainable robotic programmes. However, limited guidance currently exists on how to build and expand such programmes across different resource settings. The majority of the current guidance is mostly speciality specific and has been developed in high income countries, with limited numbers of recommendations (Supplementary Material). Developing key criteria and high quality, evidence-based guidelines to underpin the development and expansion of robotic programmes is essential to delivering high quality clinical care, training and education and research and innovation in this setting. The aim of the RoboDev study was to develop a universal framework to guide the development and expansion of robotic programmes globally, across a range of healthcare settings and surgical specialities.

Methods

An international Delphi study was conducted in keeping with the CREDES guidance (Conducting and Reporting Delphi Studies)8. This involved four phases: 1) Item generation, 2) Design and Pre-testing Delphi Questions, 3) Accelerated Delphi, and 4) Consensus Meeting.

Given the global nature of this Delphi, we divided stakeholders into socioeconomic groups based on the thresholds defined by the World Bank. The World Bank's income classification divides countries into four categories based on their gross national income (GNI) per capita[9]:

- Low-income countries are those with a GNI per capita of $1,135 or less.
- Lower-middle-income countries are those with a GNI per capita between $1,136 and $4,495.
- Upper-middle-income countries are those with a GNI per capita between $4,496 and $13,935.
- High-income countries are those with a GNI per capita of more than $13,935.

Phase I: Item Generation

A scoping review of current evidence and guidance on developing RAS surgical programmes was undertaken. Systematic searches were undertaken of the Pubmed, Embase and Medline databases between January 2000 and April 2024, as well as published guidelines by key organisational and regulatory bodies. A standardised data extraction form was developed and all relevant recommendations were extracted. Data extraction was undertaken by a single researcher (AA) and independently verified by a second researcher (JB/DH). Any discrepancies in data extraction were resolved through discussion with all three researchers Extracted key recommendations were mapped into domains using the principles of content analysis[10].

Phase II: Design and Pre-testing of the Delphi

The Delphi questionnaire was designed based on the domains generated from Phase I. Key recommendations were developed as statements for each identified domain and pre-tested with a group of international experts. Experts were selected based on their clinical and academic outputs within the field of robotic surgery or global surgery. Experts were purposively sampled across a range of surgical specialities, healthcare settings and geographical location. The Delphi questionnaire was pre-tested online with an expert panel of 36 experts, with an emphasis on content, format, acceptability and comprehension.

Phase III: Accelerated Delphi Questionnaire

An accelerated Delphi study was undertaken with two sequential voting rounds and a feedback round

was conducted, with each Delphi round open for 10 days. Each domain was listed with a definition and a corresponding list of recommendations for participants to vote on. Participants were invited to participate in the Delphi study through email distribution lists, social media platforms, professional networks and targeted invitations. The principles of snowball recruitment were utilised to recruit participants. Recruitment was designed to ensure balanced representation across multiple clinical specialities, with understanding that some specialities use RAS more than others. The study management group were engaged to leverage existing regional, national and international specialty-specific networks to enhance recruitment. We also collaborated with the GlobalSurg network to disseminate the Delphi questionnaire to a diverse population of surgeons. Formal consent was not sought, however, implied through the participation and completion of the Delphi rounds. The minimum sample size for the multistakeholder Delphi was set at 60-80 participants overall, with a sample size of 20-30 per each socioeconomic stakeholder group[11].

Participants were asked to consider each domain of the Delphi and score each recommendation based on its importance for inclusion into a future guideline for developing and expanding RAS services. All recommendations were scored on a 5-point Likert scale, with 1 being 'strongly agree' to 5 being 'strongly disagree' for inclusion into a future guideline. These scores were grouped into three categories; 1-2 (critical importance), 3 (important but not critical), 4-5 (of limited importance). Following the first Delphi round, the scores for each recommendation were calculated and were classified as 'for inclusion', 'for exclusion' or 'no consensus'. Consensus was defined as:

- For inclusion: more than 80% of respondents across all stakeholders or within an individual stakeholder group rate the recommendation as critically important and less than 15% of respondents rate the outcome as of limited importance.

- For exclusion: more than 80% of respondents across all stakeholders or within an individual stakeholder group stakeholder group rate the outcome as of limited importance and less than 15% of respondents rate the outcome as of critical importance.

Recommendations which did not achieve consensus either globally or within specific socioeconomic stakeholder groups were carried forward into Round 2 Delphi voting. To ensure the development of contextually relevant guidelines, four individual Delphi questionnaires were devised for round 2 for each socioeconomic stakeholder group.

Following the completion of Round 2 of the Delphi, a representative sample (10%) from each socioeconomic stakeholder group were sent an APEASE (Acceptability, Practicability, Effectiveness, Affordability, Spill-over effects, and Equity) questionnaire[12]. The aim of this questionnaire was to determine the appropriateness of the recommendations which achieved consensus for inclusion. The APEASE criteria assesses whether the recommendations were appropriate to stakeholders (acceptable), able to be delivered as planned (practical), potentially clinically or cost-effective (effectiveness), could be reasonably implemented and accessed by the target population (affordable), considered with regards to its potential intentional and unintentional consequences (spill-over effects), and potential to decrease or increase disparities within the target population (equity). Each recommendation was scored on an APEASE grid on a numerical scale of 1 – 10 for the APEASE domains of Acceptability, Practicability, Effectiveness, Affordability and -5 to +5 for the APEASE domains of Spill-over effects, and Equity.

Phase IV: Consensus Meeting

Three virtual consensus meetings were held using Zoom (Zoom Video Communications, Inc., San Jose, California, U.S.) to accommodate the differing time zones of the participants. The aim of the consensus meeting was to agree the final recommendations for inclusion into the guideline and to provide an opportunity for discussion. Participants who had completed both rounds of the Delphi survey and expressed an interest in participating in the consensus meeting were invited to participate. Additional invitations were sent through professional networks to target clinical and academic experts in robotic surgery and global health.

Participants were sent a summary of the RoboDev study prior to the meeting. The consensus meeting was chaired by the Chief Investigator (DH) who has experience in consensus methodology and facilitation. The meetings were audio recorded to capture key aspects of discussion. Each domain of the guideline was presented, outlining the recommendations which had achieved consensus for inclusion across all socioeconomic stakeholder groups first, followed by any recommendations which had achieved consensus for exclusion. Participants were asked if they agreed or disagreed with the inclusion/exclusion of these recommendations. Following this, recommendations classified as 'no consensus' either globally or within a specific socioeconomic stakeholder group were presented. These outcomes were discussed in detail, balancing views for and against inclusion, and the relevance to all socioeconomic stakeholder groups. Following discussion, participants were invited to vote on each recommendation anonymously using the polling function within Zoom; voting yes or no to the addition of the recommendation to the overall guideline. At least 70% of the participants had to vote, with a threshold of 80% to pass for inclusion into the guideline. Recommendations which achieved consensus for inclusion were included in the global guideline. Recommendations which did not achieve consensus were correlated with the results of the Round 2 Delphi, and were retained for inclusion for individual socioeconomic stakeholder groups if they achieved consensus within this voting round. This approach ensured the development of contextually relevant guidelines for each socioeconomic group to develop RAS services.

Results

Literature Search

Fourteen studies/guidelines were identified for inclusion[13-25] (Supplementary material). This included 4 pan-speciality guidelines. The remaining studies/guidelines focused on soft-tissue surgical specialities (Urology = 4, Thoracics = 2, Colorectal =1, Hepatobiliary = 1, Gynaecology = 1), with only one guideline focusing on Orthopaedic surgery. All identified studies/guidelines originated from HICs. A total of 133 individual recommendations were extracted from the literature. The identified 133 recommendations were expanded to 245 statements (new recommendations) to include appropriate detail for a future guideline. These recommendations were categorised into eight domains; Business Plan (36 recommendations), Oversight Committee (22 recommendations), Operational Group (27 recommendations), Clinical Leadership (15 recommendations), Industry Partnership (15 recommendations), Robotic Training (106 recommendations), Informed Patient Consent (5 recommendations), and Robotic Programme Expansion (19 recommendations). A Delphi questionnaire was designed on this basis and was pre-tested with the RoboDev Steering Committee.

International Delphi

1000 participants completed Round 1 of the RoboDev Delphi, with 595 (59.5%) HIC, 176 UMIC (17.6%), 210 (21.0%) LMIC and 19 (1.9%) LIC participants. Round 2 was completed by 812 participants, with 512 (63.0%) HIC, 135 (16.6%) UMIC, 152 (18.7%) LMIC and 13 (1.6%) LIC participants (supplementary material). The overall attrition rate between the two Delphi rounds was 18.8% (n=188). Participant characteristics are highlighted in Table 1a and 1b. Sixteen 'new' statements/recommendations were considered for suggestion following Round 1 Delphi voting. Following discussion with the steering committee, four of these were taken forward for scoring across all four sub-Round 2 Delphi questionnaire (supplementary material). Three of the statements were incorporated into the Business Case Development domain and one into the Oversight Committee domain (Supplementary material). The remaining statements were considered to be duplicates. Following completion of Round 2, 211 recommendations achieved international consensus across all the socioeconomic stakeholder groups, with consensus for inclusion for 186 recommendations and consensus for exclusion for 25 recommendations. 38 recommendations did not reach overall international consensus, with varying consensus across differing socioeconomic groups, and were therefore taken forward for discussion. Details of all Round 2 Delphi outcomes are reported in the supplementary material.

Table 1a: Delphi Participants Demographics

Variable	Number (%)
Experience/Interest in RAS	
I am currently setting up a RAS programme in my hospital	107 (10.7)
I am interested in setting up a RAS programme in the future	541 (54.1)
I have already set up a RAS programme in my hospital	291 (29.1)
None of the Above	61 (6.1)
Hospital Setting	
Tertiary Academic Center/University Hospital	730 (73.0)
District General Hospital/Rural/Referral Hospital	145 (14.5)
Private Hospital	94 (9.4)
Other	31 (3.1)
Established Robotic Programme	
Yes	478 (47.8)
No	382 (38.2)
Under development	129 (12.9)
N/A	11 (1.1)
Current MIS Experience	
Established expertise in traditional MIS with NO experience in RAS	213 (21.3)
Established expertise in traditional MIS AND established expertise in RAS	209 (20.9)
Established expertise in traditional MIS and currently training in RAS	183 (18.3)
Training in traditional MIS with NO experience in RAS	167 (16.7)
Training in traditional MIS AND training in RAS	100 (10.0)
No experience in MIS	85 (8.5)
MIS not widely used in my specialty	43 (4.3)
Clinical Role	
Consultant/Attending Surgeon or equivalent	501 (50.1)
Training Surgeon/Resident/Fellow or equivalent	237 (23.7)
Chief of Surgery / Clinical Director / Head of Department	180 (18.0)
Consultant/Attending Anaesthetist or equivalent	32 (3.2)
Medical Student	24 (2.4)
Industry Partner	6 (0.6)
Non-doctor Robotic Assistant/Surgical Care Practitioner or equivalent	6 (0.6)
Researcher	7 (0.7)
Principal Research Officer	1 (0.1)
Operation Theatre Nurse	4 (0.4)
Other	2 (0.2)
Surgical Specialty	
Colorectal Surgery	238 (23.8)
Hepatopancreaticobiliary Surgery	88 (8.8)
Upper Gastrointestinal Surgery	80 (8.0)
Orthopaedics	65 (6.5)
Emergency General Surgery & Trauma	65 (6.5)
Urology	56 (5.6)
Gynaecology	58 (5.8)
Paediatrics	51 (5.1)
General Surgery	29 (2.9)
Hernia / Abdominal Wall	26 (2.6)
Neurosurgery	25 (2.5)
Thoracic Surgery	25 (2.5)
Cardiac	19 (1.9)
Ears, Nose and Throat / Otolaryngology	18 (1.8)
Breast	16 (1.6)
Ophthalmology	16 (1.6)
General Surgery	14 (1.4)
Endocrine	13 (1.3)
Vascular	13 (1.3)
Anaesthesia	13 (1.3)
Medical student	11 (1.1)
Plastics	10 (1.0)
Surgical Oncology	10 (1.0)
Not Applicable - Industry Partner	9 (0.9)
Oral and Maxillofacial	8 (0.8)
Transplant	7 (0.7)
Other	17 (1.7)

Consensus Meeting

Three online consensus meetings were held to account for the differing time zones, with a total of 10 participants from the UK, Germany, Colombia, Brazil, and India. Participant characteristics are highlighted in Table 2. There were no recommendations which had reached consensus for inclusion through the Delphi voting which required further discussion or clarification by the group. Eight recommendations achieved consensus for inclusion into the global guideline, with ten recommendations achieving consensus for exclusion and twenty recommendations not reaching global consensus. Of the 30 recommendations which were not included in the global guideline, 3 recommendations were retained for the HIC guideline, 13 recommendations retained for the UMIC guideline, 12 recommendations for the LMIC guideline and 19 recommendations for the LIC guideline. This was based on these recommendations achieving consensus for inclusion within these individual stakeholder groups during round two of the global Delphi.

APEASE Criteria

A total of 249 participants completed the APEASE questionnaire, with 162 participants from HIC, 43 from UMIC, 40 from LMIC and 4 from LIC. Summary APEASE scores for the entire guideline are outlined in Table 3. Summary APEASE scores for each domain and individual recommendation are outlined in the supplementary material. Overall, the guidelines were considered to be acceptable, practical, and effective. The affordability of the recommendations were considered to be similar across all four socioeconomic stakeholder groups. Overall, the wider benefits to the healthcare systems were minimal across HIC, UMIC and LMIC. The greatest impact of developing and implementing RAS programmes was considered to be in the LIC setting, with the highest impact on healthcare services and staff, with a spill-over effect of 2.9 for the entire guideline. Spill-over scores were consistently higher across all recommendations in the LIC guideline compared to the other stakeholder groups. LICs also expressed the highest impact regarding the development of equitable RAS programmes, with the highest APEASE score on the equity domain.

Guidelines

A total of 249 recommendations were voted on across two Delphi rounds, with 186 recommendations achieving consensus for inclusion, 25 recommendations achieving consensus for exclusion and 38 recommendations being carried forward into the consensus meeting. Following the consensus meeting, a further 8 outcomes achieved global consensus and were included in the final global guideline. The final global guideline consists of 194 recommendations which are relevant to all socioeconomic settings (Figure 1). The HIC guideline consists of 3 additional recommendations, totalling 197 recommendations when combined with the global guideline. The UMIC guideline consists of 13 additional recommendations consisting of 207 recommendations overall. The LMIC guideline consists of 12 additional recommendations consisting of 206 recommendations overall. The LIC guideline consists of 19 additional recommendations consisting of 213 recommendations overall. The domains with differing recommendations across the different socioeconomic stakeholder groups included Business Plan, Oversight Committee, Operational Group, Clinical Leadership, Robotic Training (subdomains of Simulation Training, Peer-to-Peer support and Oversight), and Robotic Programme Expansion.

In the Business Case domain, LMIC and LICs included the contribution of robotic engineers to the development of the business case as essential. During the consensus meeting, participants explained, this was essential to ensure theatre ‘readiness’ and appropriate infrastructure to support the new implementation of RAS services. Potential changes to infrastructure, the need for electricity supplies and internet connectivity need to be accounted for and addressed within the business plan in these settings. Overall, LMICs and LICs, recommended a wider range of personnel involved in the business plan development, with LICs including surgical trainees, senior anaesthetists and regional health board members. The inclusion of wider members of the multidisciplinary healthcare team was also recommended in the makeup of the Operational Group. This likely reflects the organisation of teams within healthcare systems in LMICs and LICs and the need for a collaborative approach in implementing new technology. The delivery of RAS training was broadly

universal across all socioeconomic groups; UMIC and LIC participants recommended that simulation training should be delivered across all modalities, including the robotic console, virtual reality headsets, laptop devices and mobile phones, in a bid to expand access to as many healthcare professionals and to ensure equity of training.

Discussion

The RoboDev Delphi study represents a comprehensive, international effort to standardise the development and expansion of RAS programmes globally. We have developed a global guideline of 194 recommendations applicable across all healthcare settings, with additional tailored recommendations for high-, upper-middle-, lower-middle-, and low-income countries. This approach acknowledges the universal elements necessary for safe and sustainable RAS implementation and the contextual adaptations needed to address specific infrastructural, economic, and workforce challenges within individual healthcare systems.

We identified eight core domains critical to the establishment of RAS programmes: business planning, oversight committees, operational groups, clinical leadership, industry partnerships, robotic training, informed patient consent, and programme expansion. Whilst consensus was cohesive across most domains, variation emerged in areas such as infrastructure readiness, training modalities, and the breadth of stakeholder engagement across world income groups. Our results highlight both the universality and contextual variation in what is required to build sustainable RAS programmes. Across all income groups, participants agreed on the importance of structured business planning, formal oversight mechanisms, robust training pathways, and strategic partnerships with industry. In HIC countries, the focus was on governance, quality assurance, and standardisation—reflecting established infrastructure and existing RAS penetration. In contrast, LMICs and LICs prioritised foundational considerations such as reliable electricity, internet connectivity, infrastructure readiness, and equitable access to training. The inclusion of engineers, senior anaesthetists, and local health board representatives in planning processes illustrates the pragmatic and multidisciplinary approach necessary

Figure 1: Study flowchart

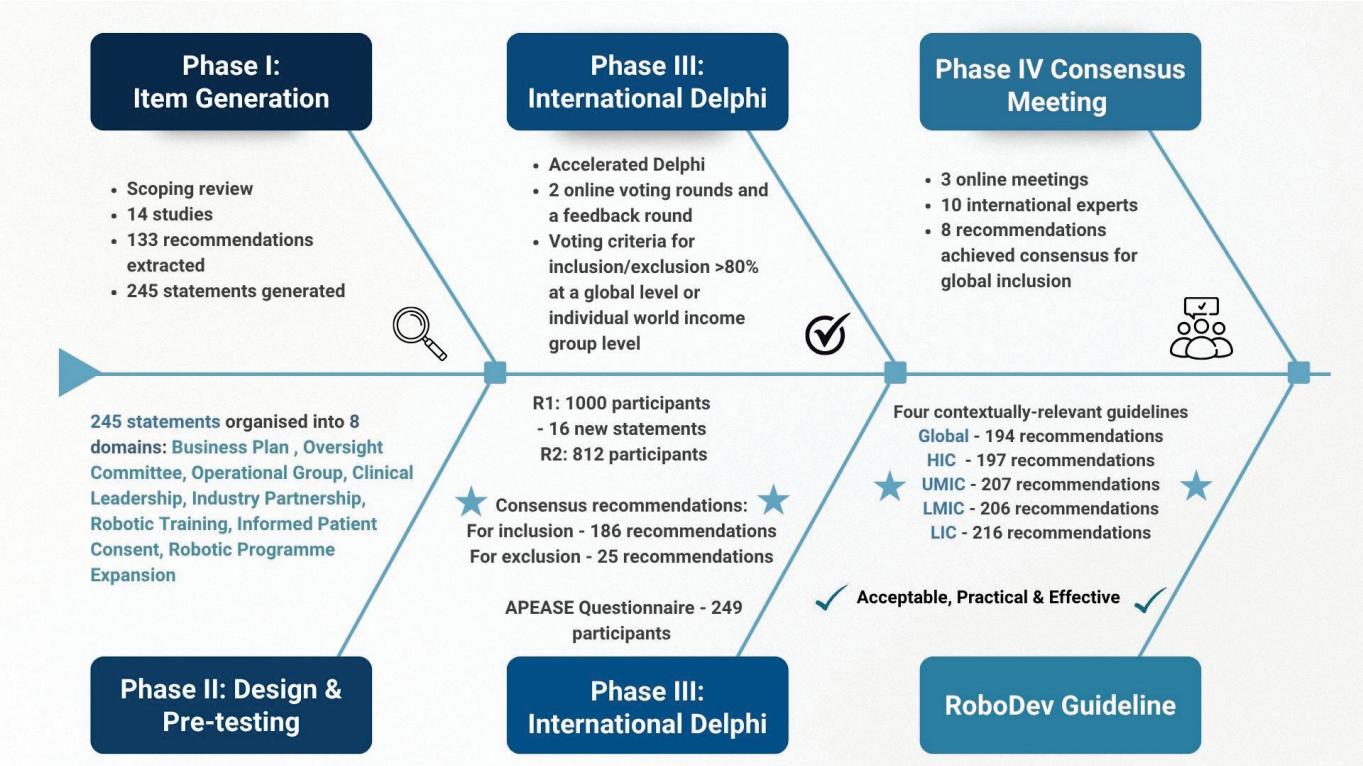

Table 1b: Delphi Participants Demographics

Variable	Number (%)
World Bank Income Groups	
High Income Country	595 (59.5)
Upper Middle-Income Country	176 (17.6)
Low Middle Income Country	210 (21.0)
Low Income Country	19 (1.9)
Gender	
Male	790 (79.0)
Female	207 (20.7)
Prefer not to say	3 (0.3)
Country (top 10)	
Italy	157 (15.7)
United Kingdom	143 (14.3)
India	78 (7.8)
Spain	49 (4.9)
Türkiye	48 (4.8)
Nigeria	47 (4.7)
Greece	42 (4.2)
United States of America	26 (2.6)
Germany	26 (2.6)
Egypt	22 (2.2)
Existing Robotic Platform*	
Da Vinci	106 (27.5)
Da Vinci Xi	79 (20.5)
Da Vinci X	48 (12.5)
Stryker Mako	33 (8.6)
Medtronic Hugo	28 (7.3)
Da Vinci Si	22 (5.7)
CMR Versius	18 (4.7)
Da Vinci SP	6 (1.6)
Smith & Nephew Cori	6 (1.6)
Zimmer Biomet Rosa	6 (1.6)
Da Vinci 5	5 (1.3)
Senhance	4 (1.0)
SSI Mantra	4 (1.0)
Da Vinci S	3 (0.8)
DePuy Velys	2 (0.5)
Dexter	2 (0.5)
Excelsius	2 (0.5)
Symani Surgical System	2 (0.5)
BrainLab Cirq Robotics	1 (0.3)
Eyesi surgical simulator	1 (0.3)
Freehand Robot	1 (0.3)
Mazor	1 (0.3)
MicroPort SkyWalker	1 (0.3)
Mira	1 (0.3)
Navio	1 (0.3)
Renishaw	1 (0.3)
Sony	1 (0.3)

**385 responses to this variable; see supplement for full list of participating countries*

Table 2: Consensus Meeting Participant Demographics

Variable	Participants (%)
Gender	
Male	6 (60)
Female	4 (40)
Surgical Speciality	
Breast Surgery	1 (10)
Cardiac Surgery	1 (10)
Colorectal Surgery	4 (40)
Ear, Nose and Throat	1 (10)
Gynaecology	1 (10)
Orthopaedics	1 (10)
Plastic Surgery	1 (10)
Socioeconomic Classification	
High Income Country	7 (70)
Upper Middle-Income Country	1 (10)
Low Middle Income Country	2 (20)

in resource-constrained environments. Training emerged as a domain of particular divergence, with HICs prioritising simulation and peer-to-peer mentoring within established robotic centres. In contrast, LMICs and LICs highlighted the need for low-cost, scalable training solutions accessible beyond tertiary hospitals. Recommendations to integrate VR headsets, laptops, and mobile phones into training pathways reflect a strong commitment to equity, ensuring that technological advances do not exacerbate existing disparities in surgical access and training. Our findings reinforce the principle that RAS cannot be developed as a "one-size-fits-all" intervention. Guidelines in this setting must be adaptable, flexible, and responsive to local resource constraints and opportunities.

Previous works on RAS programme development have been speciality specific focusing on a single robotic vendor within HIC settings, with several reports of successful implementation of RAS programmes across a range of surgical specialities and healthcare systems[26-29]. Successful implementation is usually benchmarked against perioperative clinical standards ensuring outcomes are not adversely impacted during the initial adoption phase of RAS. There is little emphasis on implementation frameworks to guide the development of the overall RAS programmes in robotic naïve clinical settings, with no benchmark standards available to assess the quality of the operational and implementation aspects of RAS programmes. This reflects the lack of high-quality data underpinning existing guidelines. Our literature search identified 14 studies/guidelines addressing the set-up of RAS programmes, all of which originated from HICs, with a focus largely on soft-tissue surgical specialities. The robotic landscape has significantly shifted in the last 5 years, with multiple new RAS platforms emerging for a range of surgical indications[30]. It is essential that new and emerging guidelines reflect the evolving and dynamic nature of RAS across all surgical specialities and income groups. RoboDev provides a platform-agnostic, pan-speciality, evidence-informed globally applicable framework for RAS implementation, with key criteria and benchmarks to ensure successful and sustainable programmes.

The RoboDev guidelines have important implications for healthcare providers, policymakers, and industry partners. At a hospital and institutional level, they provide a structured framework for planning and implementing RAS programmes, from initial business case development to long-term expansion and quality assurance. For governments and health ministries, the guidelines offer a roadmap to ensure that investment in surgical robotics are evidence-based, sustainable,

Table 3: Summary APEASE Scores for the RoboDev Guidelines

APEASE Criteria	HIC	UMIC	LMIC	LIC
Acceptability	8.5	8.5	8.9	9.1
Practicability	8.1	8.3	8.5	8.6
Effectiveness	8.2	8.3	8.5	8.5
Affordability	7.8	8.0	7.9	7.7
Spill Over Effects	0.9	1.2	0.3	2.9
Equity	1.1	1.8	1.5	3.1

and aligned with health system priorities. In LMICs and LICs, the RoboDev guidelines provide policy-makers with context-specific recommendations, as these settings are rarely considered in existing guidelines[7, 31]. The RoboDev recommendations may help mitigate the risks of inappropriate technology adoption by ensuring that infrastructure readiness, supply chain, workforce training and affordability are prioritised. RoboDev also addresses the importance of equity within these settings, thus aligning with wider global health priorities, including the World Health Organisation's mandate to reduce surgical disparities and the Lancet Commission on Global Surgery's call for equitable access to safe surgical care[32,33].

RoboDev represents an unprecedented global effort in establishing a high-quality framework for RAS programmes, addressing key aspects of programme development, including operational requirements, workforce training and programme expansion. Our consensus methodology had widespread surgical, geographical and socioeconomic representation. A key strength of our work is developing recommendations that are acceptable, practical, affordable and equitable across all settings based on the APEASE criteria. This approach will help ensure the future implementation of our guideline. A key limitation of our work is the comparatively low sample size of participants from LICs. This is likely to represent the current penetration and enthusiasm for RAS in this setting. Although participation was lower in LICs, we ensured their perspectives were captured in our analysis and these voices were given equal weight in consensus decisions. As the RAS market in LMICs and LICs expands, it will be important to reassess the relevance and applicability of our RoboDev guideline in this setting. Furthermore, our consensus meeting consisted of a small number of participants, which may have introduced selection effects which may have potentially shifted the balance of recommendations. It is also important to note that the majority of recommendations lack high quality evidence and are a reflection of expert judgment and opinion, as the evidence-base in RAS continues to develop these guidelines will require refinement and update. Future works will also need to assess and evaluate the impact of guideline adoption on developing new RAS programmes, with an emphasis on clinical outcomes, workforce development and healthcare system efficiency. Furthermore, as the RAS landscape continues to expand, with growth in LMIC and LIC settings, future updates of this guidance will require greater representation from these groups.

RoboDev represents the first step towards harmonisation of standards for RAS programme development and training curricula on a global scale, thus supporting the vision of equitable and safe expansion of robotic surgery worldwide.

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