



Development and early implementation of a platform-agnostic robotic surgery curriculum

Daniel Costello^{1,2,5}, Jade El Mohamed^{1,2}, Kirsten Larkins^{1,2}, Satish Warriar^{1,2}, Alexander Heriot^{1,2,3}, Matt Gray¹, Grace Burke^{1,2}, Dean Driscoll¹, Owen Niall^{1,5}, Ben Challacombe⁴, Nicholas Raison⁴, Tayla Fay^{1,2}, Claire Salmon^{1,2}, Sophie Tisot^{1,2}, Anthony Costello^{1,2}, Helen Mohan^{1,2,3}

Correspondence: Daniel Costello, International Medical Robotics Academy (IMRA), Melbourne, Australia.
Email: drdancostello@gmail.com

Abstract

Background: Access to standardised high-fidelity training in robotic surgery is uneven and most programmes are tied to a single vendor. We developed and evaluated an educational curriculum designed to be platform-agnostic and deliverable at scale.

Methods: We conducted a prospective, mixed-methods evaluation of a modular curriculum delivered at the International Medical Robotics Academy and affiliated laboratories (February 2020–September 2025). Components included online foundations, virtual-reality simulation, component and whole-procedure simulations, and non-technical skills training with emergency undocking drills. Participants were consultant surgeons, trainees and medical students across general surgery, colorectal, gynaecology and urology. Outcomes were completion and participation, knowledge test scores (pre/post), simulator metrics (time, economy of motion, errors), achievement of predefined competence thresholds, and Non-Technical Skills for Surgeons (NOTSS) ratings.

Results: More than 500 individuals completed at least one component. The Foundations course was completed by 190 participants as stand-alone course and by 104/118 RoboSET course participants. The medical-student subject enrolled 80 students across four iterations. RoboSET enrolled 118 participants; 70 completed all elements and the first 40 completers formed the initial analysis set. Among RoboSET participants, mean time to simulator proficiency on a validated four-module benchmark was 19 minutes (range 28). On post-course survey, 95% reported improved surgical skills and 88% increased confidence. NOTSS scenarios were completed by 70 participants; 70% reported being very satisfied and 94% judged the training relevant to practice. Simulated technical tasks on procedure models involved 277 participants; GEARS and task-specific ratings were captured, with denominators reported in the main text.

Discussion: A platform-agnostic curriculum was feasible to deliver across roles and specialties and was associated with short-term gains in knowledge, simulated technical performance and team behaviours. Multi-centre studies linking completion to theatre performance, credentialing and patient outcomes are warranted.

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Introduction

Robotic surgery was until recently dominated by a single platform. Training was heterogeneous, often vendor-led, with uneven access to expert mentorship. Preclinical exposure relied on animal and cadaver models with ethical, logistical and cost constraints. Gaps in metrics and assessment have been described^{1,2}. We developed an ethical, standardised and adaptable surgeon-led

programme spanning a range of experience levels. Core components were online learning, surgical videos, virtual-reality (VR) simulation and skills training using high-fidelity synthetic organ models^{3,4}. The programme targets both technical and non-technical skills that transfer across robotic systems, including delivery on multiple platforms when available. A hybrid model was used to make trainees “robot-ready” before hands-on exposure,

¹International Medical Robotics Academy (IMRA), Melbourne, Australia

²The University of Melbourne, Australia

³Peter MacCallum Cancer Centre, Melbourne, Australia

⁴Guy's and St Thomas' NHS Foundation Trust, London, UK

⁵St Vincent's Hospital, Melbourne, Australia



drawing on experienced robotic surgeons to shape content. Structured video, simulation and model-based training were designed to prepare participants safely for live surgery. This manuscript outlines the International Medical Robotics Academy (IMRA) preclinical curriculum and reports early learning outcomes in technical and non-technical domains prior to patient operations.

Curriculum design followed Kern's approach with a needs assessment involving trainees and trainers¹. The first component was an online Foundations in Robotic Surgery course providing core theory so learners could engage effectively in subsequent simulation or clinical placements. Multimodal courses were then built by combining online materials, simulation, VR and hands-on experience using models developed at IMRA.

An IMRA/Society for Robotic Surgeons Delphi consensus supports a multimodal approach that uses the full spectrum of simulation tools⁴. Unlike the early laparoscopic era, current training can exploit mature surgical simulation technology. Our programme integrates online didactic content, VR training, software simulators, and hands-on practice with basic, component and whole-procedure models. Attention to how video is used as an instructional tool aims to maximise educational value^{6,7}. As additional robotic systems entered practice, a single-platform focus was insufficient. We worked on the premise that core skills transfer across platforms, with platform-specific nuances addressed by targeted training. Evidence of cross-platform transfer in simulation has been reported⁸. Using all three robots available in Australia, and with industry support, the IMRA curriculum provides increased hands-on time within a platform-agnostic design. Animal models are difficult to use in theatre environments and raise cultural and biosecurity concerns; cadaver access is limited and costly, issues amplified during the pandemic. To address these constraints, hydrogel models with anatomically realistic planes suitable for dissection and cautery were developed. Hydra abdominal wall models can be insufflated for port placement and set-up. Classified as "wet models", they replace animal or cadaver tissue in the pathway. Their bioinert properties, postal delivery and room-temperature storage enable scalable, standardised training.

Robotic surgery separates the console surgeon from the bedside team, reducing traditional non-verbal instruction and creating communication challenges and opportunities⁹. Few studies focus on non-technical training in robotics; deliberate preparation for critical events such as undocking is important¹¹. From early in the programme, human-factors expertise informed design. In RoboSET, a half-day is devoted to non-technical skills in an immersive operating-theatre simulation with actors and hydrogel models, followed by structured debrief using a NOTSS-style format. Scenarios include emergency undocking. Non-technical training remains

integral to course development to support safe practice.

Methods

About IMRA

The International Medical Robotic Academy was established in 2019 initially as the Australian Medical Robotics Academy (AMRA) with the aim of delivering onsite robotic training. However, as COVID hit it rapidly became apparent that the traditional model of training to centralised sites for robotic training was not sustainable. Instead, options for online training and for developing models that were biologically inert and able to be used locally in hospitals were explored. IMRA subsequently commercialised and rebranded as the International Medical Robotics Academy and currently develops and manufactures training models and runs courses at the central site in Melbourne and internationally in collaboration with other units and in local hospital settings using novel models generated at IMRA.

Study design and setting

A prospective mixed-methods evaluation was undertaken at the International Medical Robotics Academy (IMRA) between February 2020 and September 2025. Training was delivered online and through IMRA-affiliated simulation laboratories using three different robotic platforms. A six-week discovery subject was developed with the University of Melbourne. For trainees and surgeons new to robotics, a pathway was created from assisting to basic console skills (RoboSET), followed by component/procedural simulations (e.g., right hemicolectomy intracorporeal anastomosis, partial nephrectomy). RoboSET is a two-day course with dedicated non-technical skills; a one-day condensed RoboSTART variant was delivered in Australia and internationally. Both are accredited by the Royal Australasian College of Surgeons. Component and whole-procedure courses, plus train-the-trainer programmes, were added.

Participants

Participants included consultant surgeons, trainees, and medical students from general surgery, colorectal, gynaecology, and urology. All completed at least one element of the curriculum. Participation was voluntary and fitted around service commitments.

Robotic Systems

Three surgical robotic platforms were used in this curriculum. These included the DaVinci[®] Xi robot (Intuitive Surgical), the HUGO[™] RAS System (Medtronic) and the Versius Robotic System (CMR Surgical). Each of these robotic systems have three core components: a surgeon console enabling 3D-vision, a patient cart and a vision tower. Features within these components vary between systems. For example, the DaVinci[®] 327Xi robot has a



closed surgeon console and a pincer grip hand control compared with the HUGO™ and the Versius robots which have open consoles and pistol grip hand-controls. Patient cart configurations, docking and instruments are unique to each system.

Curriculum (intervention)

The IMRA curriculum integrated foundation e-learning, virtual-reality (VR) simulation, synthetic organ and whole-procedure models, and non-technical skills training. It was designed as a modular rather than linear pathway, allowing entry at different points and flexible progression (summarised in Figure 1). Models used are shown in Figure 2.

Outcomes and assessment

Educational outcomes covered knowledge, simulated technical skill, and non-technical behaviours. Knowledge was measured by pre- and post-course tests within the online foundation modules.

Technical performance was evaluated through (1) GEARS (Global Evaluative Assessment of Robotic Skills), a validated five-domain rating (depth perception, bimanual dexterity, efficiency, force sensitivity, and autonomy) scored by trained assessors from recorded simulations; (2) RACE (Robotic Anastomosis Competency Evaluation), a structured task-specific tool rating accuracy of dissection, needle handling, knot tying, and suture placement. Non-technical performance was assessed using NOTSS (Non-Technical Skills for Surgeons), a behavioural

framework evaluating situational awareness, decision-making, communication, teamwork, leadership, and workload management. Ratings were completed after immersive operating-theatre simulations that included emergency undocking drills and structured debriefs.

Data collection and analysis

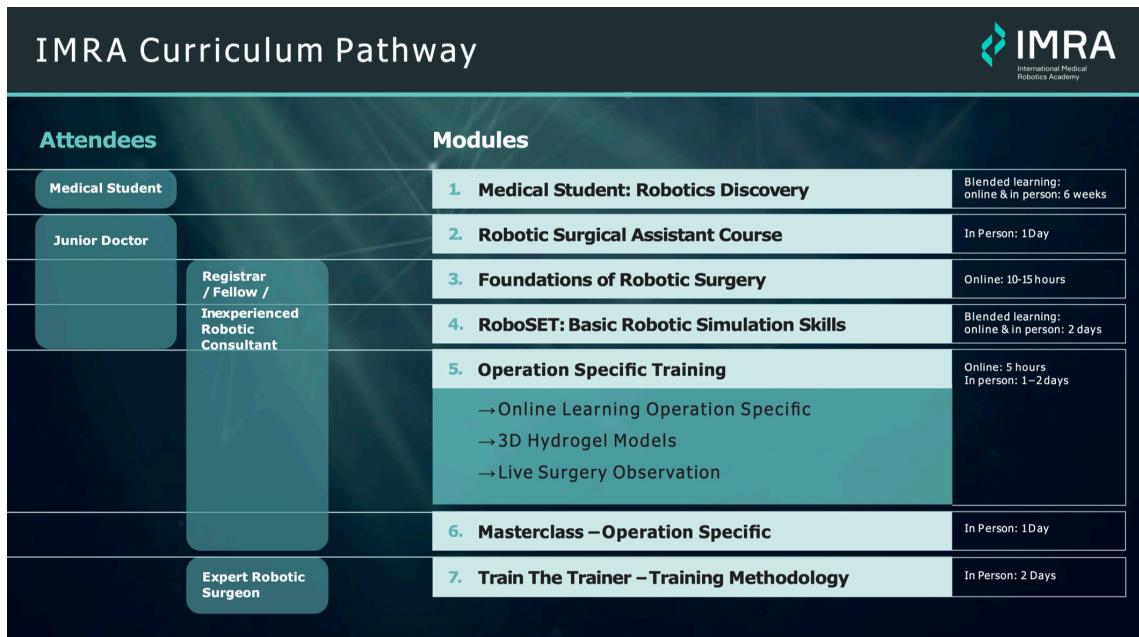
Completion rates, simulator metrics (task time, economy of motion, errors), GEARS, RACE, and NOTSS scores were recorded prospectively in the programme database. Proficiency on VR simulators was defined as equivalence to a surgeon with at least 75 robotic cases on two consecutive attempts using a four-module benchmark [13]. Data were analysed descriptively with comparisons of pre- and post-training performance and time to proficiency. This was an education/service evaluation using anonymised data; formal ethics review was not required under local policy.

Results

Study population and setting

Between February 2020 and September 2025, more than 500 participants undertook at least one component of the International Medical Robotics Academy (IMRA) curriculum, delivered online and at IMRA-affiliated surgical training laboratories using three robotic platforms (table 1). Participants included specialist surgeons from subspecialties such as general surgery, colorectal, gynaecology and urology, as well as surgical trainees and medical students. The curriculum was implemented as a

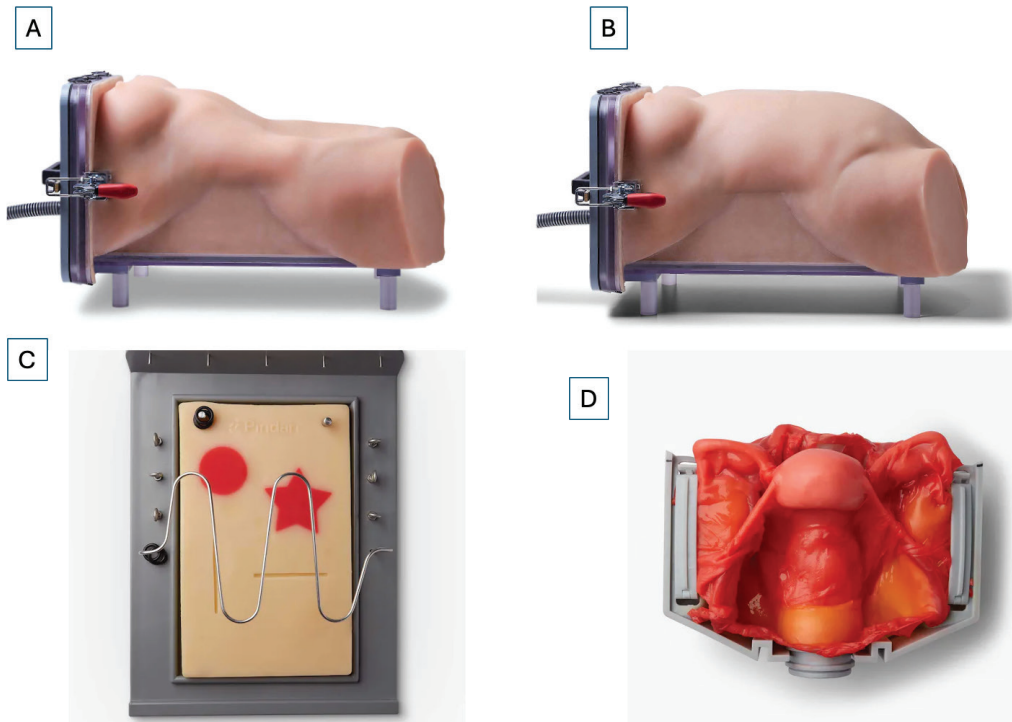
Figure 1: The IMRA Curriculum Pathway



Schematic of the curriculum pathway from online foundation learning to VR, hydrogel/Skinthetic tasks, whole-procedure simulations and non-technical skills, including emergency undocking drills. Assessment points are shown at each stage.



Figure 2: Hydrogel and Skinthetic Models



A-Hydra Insufflatable Skinthetic Model; B-Dadbod Insufflatable Skinthetic Model; C-Hydroskin training model; D-Example of a Whole Procedural Model (Hysterectomy)

modular, adaptive programme rather than a fixed linear sequence, allowing flexible entry points and progression according to individual trainee needs.

Curriculum components and delivery

The Foundations of Robotic Surgery online course included ten modules and was completed in two phases. First, a stand-alone course was completed by 190 participants with assessment and amendments led by the Royal Australian College of Surgeons. Secondly, as a primer for RoboSET, the online course was completed by 104 of 118 RoboSET enrolees; a score of 100% on module quizzes was required to progress. The Medical Student Robotic Surgery Discovery subject was delivered to 80 students over four iterations (2024–2025), evaluated using the Kirkpatrick model with the aim of achieving level 3 behavioural change. Post-course evaluations were completed by students. Ninety-eight per cent found the curriculum highly relevant and 100% valued robotic literacy. Overall, students reported high satisfaction and increased knowledge, skill and confidence in managing patients undergoing robotic surgery.

The RoboSET course was attended by 118 participants, with 70 completing all components (Foundations primer, the Innate Ability VR curriculum, Hydroskin Trainer and NOTSS). Analysis of the first 40 completers is summarised here. All participants were robotic surgery novices with a maximum of ten cases as primary robotic operator prior

to the course. The mean time to proficiency on the four-module VR simulator programme was 19 minutes. The gap between the fastest and slowest participants was 28 minutes [13]. GEARS and RACE scores were measured for dissection and suturing tasks on the Hydroskin trainer using three robotic surgery platforms. All participants thought the multiplatform exposure was advantageous; 95% reported improved surgical skills and 88% reported improved confidence post-course.

Robotic surgical experts provided NOTSS scenarios based on real-life experiences unique to robotic surgery. A fully immersive operating theatre environment, equipment, sounds and characters were developed. Scenarios were critiqued by surgeons, education and simulation experts and a professional actor. Guidelines for debrief using Pendleton's method were created, and assessment parameters aligned with RACS criteria. Multiple twenty-minute NOTSS scenarios were completed by 70 participants; 85% responded to a survey, 70% were very satisfied, and 94% felt the training was relevant and transferable. Supervising surgeons and NOTSS experts most often identified needs in communication, situational awareness and workload management. Emergency undocking served as a critical scenario. High-fidelity synthetic organ models were used by 277 participants across specialties. Assessment included GEARS video ratings and built-in metrics such as positive surgical margins, blood loss and leak tests. Model costs ranged



Table 1: Participation matrix

Curriculum component	Participants (n)	% of total (≈500)	Notes
Online foundation (stand-alone + primer)	294	59%	104/118 completed as RoboSET primer
RoboSET full course	118 enrolled / 70 completed	24% / 14%	40 analysed for VR metrics
RoboSTART condensed	n not recorded	-	Delivered nationally & internationally
Synthetic organ models	277	55%	Multispecialty use
NOTSS / undocking drills	70	14%	85 % response rate
Medical student discovery course	80	16%	Four iterations (2024–2025)

Modules were undertaken independently or in sequence according to trainee needs; totals exceed 500 because some participants completed more than one component.

from \$198 AUD (Hydroskin; Figure 2C) to \$500–\$1000 AUD for high-fidelity models such as the hysterectomy trainer (Figure 2D).

Outcomes and transferability

Transferability of robotic console skills using VR simulators and synthetic tissue models was demonstrated between the three robotic platforms amongst participants early in their robotic surgery training [8]. This suggested that core robotic surgery behaviours can be learned on one platform and applied to shorten the learning curve on alternative platforms.

Discussion

This evaluation shows that a multimodal, platform-agnostic curriculum for robotic surgery can be delivered at scale and used by surgeons with different backgrounds, with short-term gains across knowledge, simulated technical performance and non-technical behaviours. The pathway is simple to adopt: online foundation learning sets shared terminology and core principles; virtual-reality tasks and whole-procedure simulations provide deliberate practice with objective metrics; and team training embeds NOTSS domains and emergency undocking drills. Together these elements offer a clear route from basic familiarity to simulated readiness that fits around service pressures. The platform-agnostic design responds to a changing device landscape. Training that builds generic cognitive and psychomotor skills, then layers platform-specific controls, is more resilient to changes in suppliers and procurement. Exposure to more than one system appears feasible in routine delivery and may reduce reliance on a single console for skill acquisition. For centres expanding capacity, this can align education with procurement so workforce preparation does not limit theatre use. Short-term learning signals were consistent. Knowledge scores improved after the online foundation; simulator metrics moved in the expected direction (faster task times, better economy of motion, fewer errors); a sizeable

proportion met predefined competence thresholds for component and whole-procedure simulations; and NOTSS performance improved in targeted domains. These are Kirkpatrick Levels 1-3 outcomes and should be interpreted as educational gains in simulated settings rather than clinical effectiveness. The aim of preclinical training is to shorten the learning curve on live patients. Safety and team behaviours deserve emphasis. Emergency undocking is low-frequency but high-stakes, and most teams will not encounter a real event during training. Building undocking drills and NOTSS checklists into the core pathway normalises the behaviours and communication needed when things go wrong. This converts a latent safety risk into a trainable routine with observable steps and a simple success criterion: completion without critical error. The programme's strengths include scalability, an explicit competency map, and the blend of technical and non-technical components. Delivery across roles reflects the team nature of robotic surgery and may shorten the time to stable list running once platforms arrive. Use of objective simulator metrics and predefined pass thresholds provides transparent progression rules that learners and faculty can follow. Materials are modular and can be scheduled in short blocks, reducing the need for long releases from clinical work. Limitations are clear. This is a single-centre, early implementation with voluntary participation and no control group. Outcomes are educational rather than clinical; there are no data on transfer to operating-theatre performance, credentialing milestones or patient outcomes. Self-selection and prior experience may influence results; not all participants reached every stage, and reasons for non-completion were not systematically recorded. Differences between platforms were not analysed and the evaluation was not powered to compare devices. Claims about superiority, cost-effectiveness or service impact are therefore outside scope. Workforce and service factors matter. Training time, faculty availability, simulator access and rota cover for



whole-procedure simulations are practical bottlenecks. A curriculum delivered in short blocks with clear thresholds helps, but protected time is still needed. Centres planning rapid scale-up should align adoption timelines with realistic education schedules, including supervised ramp-up for new teams and back-fill for staff attending simulation days. Emphasising platform-agnostic skills may also help when staff move between sites. Future work should go beyond early adoption metrics. Multi-centre studies could link curriculum completion to operating-theatre performance (set-up time, turnover, case duration, escalation rates), credentialing milestones and, where feasible, patient outcomes. Follow-up at six to twelve months would test retention and the durability of NOTSS behaviours. Economic evaluation, even at the level of educator time and simulator use, would help departments plan capacity. As new platforms appear, comparative educational studies could test whether a platform-agnostic start accelerates platform-specific mastery. An ongoing programme is evaluating longer-term outcomes and novel assessment methods for the robotic training models¹⁰. In summary, a structured, platform-agnostic curriculum for robotic surgery is deliverable at scale and associated with short-term gains in simulated technical and non-technical performance across mixed teams. The model is transferable and safety-aware, but claims about clinical impact await larger, multi-centre evaluations with theatre-level endpoints.

Data availability: Anonymised summary data (course counts, completions, test scores and simulator metrics) are available in the Supplement.

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Competing interests: Dr. Helen Mohan has research funding from Proximie and is the Director of Research at IMRA for which she receives a consulting fee. Dr. Anthony Costello is on the Board of Directors and a Shareholder at IMRA. Dr. Satish Warriar and Professor Alexander Heriot receive a consulting fee from IMRA. Dr. Jade El Mohamed is a graduate researcher and undertakes paid work for IMRA. Ben Challacombe consults for Medtronic. Grace Burke has shares in IMRA and is an employee of IMRA. Dean Driscoll is a former employee of IMRA and has shares in IMRA. Claire Salmon is an employee of IMRA. Captain Matt Gray consults for IMRA. Daniel Costello and Sophie Tissot are former employees of IMRA.

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Ethics: This was an education/service evaluation using anonymised training data; formal research ethics review was not required under local policy.

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