Robot-assisted general surgery in Aotearoa New Zealand

Phillip P Chao, Jonathan B Koea, Andrew G Hill, David Resoli, Sanket Srinivasa

ABSTRACT

Robot-assisted surgery refers to a surgeon controlling a robotic device that performs an operation. This viewpoint explores the current state of robot-assisted surgery in Aotearoa New Zealand using the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, California, United States), the only currently available robotic surgical system for general surgery in the country. We describe the contemporary progress in Aotearoa New Zealand compared to Australia and globally, and present emerging high-level evidence from randomised controlled trials regarding the utility of the robot-assisted approach for general surgery procedures. From the available evidence, we suggest that the value of robot-assisted general surgery in the public healthcare system arises from its emerging clinical benefits for complex procedures and its potential to engender equitable access and outcomes, particularly for Māori and Pacific peoples, improve education and training and contribute towards quality assurance and workforce development. Therefore, its implementation aligns with the New Zealand Health Strategy's long-term goals and priority areas to achieve pae ora, a healthy future for all.

Robot-assisted surgery (RAS) refers to a surgeon controlling a robotic device that performs an operation. In its simplest iteration, it is an extension of surgical instruments and is not autonomous as it remains under the complete control of the operating surgeon. The first approved robotic surgical system (RSS) for clinical use in general surgery was a robot-assisted camera holder for laparoscopic surgery in 1993.[1] The da Vinci Surgical System (dVSS) (Intuitive Surgical, Sunnyvale, California, United States [US]) received approval from the US Food and Drug Administration (FDA) in 2000 and has been the dominant RSS used in general and abdominal surgery.[1]

Robotic surgical systems for general surgery in Aotearoa New Zealand

There are various other RSS for general surgery available,[1] such as the Hugo (Medtronic, Dublin, Ireland) and Versius (CMR Surgical, Cambridge, United Kingdom) in Australia; however, to the best of our knowledge, these are not yet currently available in Aotearoa New Zealand. The first surgery using the dVSS in Aotearoa New Zealand was robot-assisted radical prostatectomy performed in 2007,[2] and there are currently seven dVSS in operation in the country. North Shore Hospital is the only public hospital with a dVSS, and its first robot-assisted general surgery procedure was performed in late 2022.

The RAS-specific code was only introduced to the National Minimum Dataset for hospital events in 2019, and despite its implementation it has been variably applied (communications with National Collections and Reporting, Manatū Hauora – Ministry of Health). Therefore, the data presented here utilise anonymous procedure-only information from the Aotearoa New Zealand distributor of the dVSS (Device Technologies, Auckland, New Zealand) akin to other published work in this area.[3,4]

A total of 4,709 operations using the dVSS have occurred in private hospitals in Aotearoa New Zealand from 2007–2022. The number per year increased almost sevenfold, from 110 in 2008 to 743 in 2022 (Figure 1). For an initial 7 years, from 2007–2013, the dVSS was solely used for urological surgery, until the first cases of gynaecology and general surgery were recorded in 2014, and head and neck in 2016.

The numbers of procedures and proportions in each of the defined categories are shown in Table 1, along with the five most frequently performed surgical procedures overall and their proportions in their respective category.

Among the 16 recorded general surgery procedures are rectopexy, cholecystectomy, distal pancreatectomy, liver resection, liver cystectomy and ventral/incisional hernia repair.

RAS with the dVSS in Australia and globally

In Australia, the dVSS was the only robotic platform to perform soft tissue operations until the

limited entry of other platforms in 2018.[3] Using the same data source,[4] Table 2 compares the number of cases and systems available in Australia and Aotearoa New Zealand from 2015 to 2020. There was a similar rate of annual increase in the number of cases between the countries. In 2020, Australia had over double the number of dVSS per capita (2.6 vs 1.0 per 1 million) but performed almost five times the number of cases per capita (543 vs 109 per 1 million) as a result of the almost twice as many cases performed per RSS (208 vs 111).

Australia has seen a decreasing proportion of urology cases due to the expansion to other specialities, with urology accounting for 68% and gynaecology for 15% of cases in 2020, compared with 88% and 10% in Aotearoa New Zealand, respectively.[4,5] No detailed analysis of the numbers and types of all general surgery cases in Australia has been published, except pertaining to robot-assisted colorectal surgery.[3] There were 6,110 robot-assisted general surgery cases using the dVSS in Australia between 2010 and 2019 with colorectal procedures accounting for 57.6%.[3]

World-wide, there were over 1.8 million procedures done utilising over 7,500 dVSS in 2022, with general surgery being the most rapidly growing and largest category—comprising almost half of all procedures—followed by urology and then gynaecology.[6]

Figure 1: Trend of robot-assisted surgery utilising the da Vinci Surgical System in Aotearoa New Zealand private hospitals from 2007–2022.

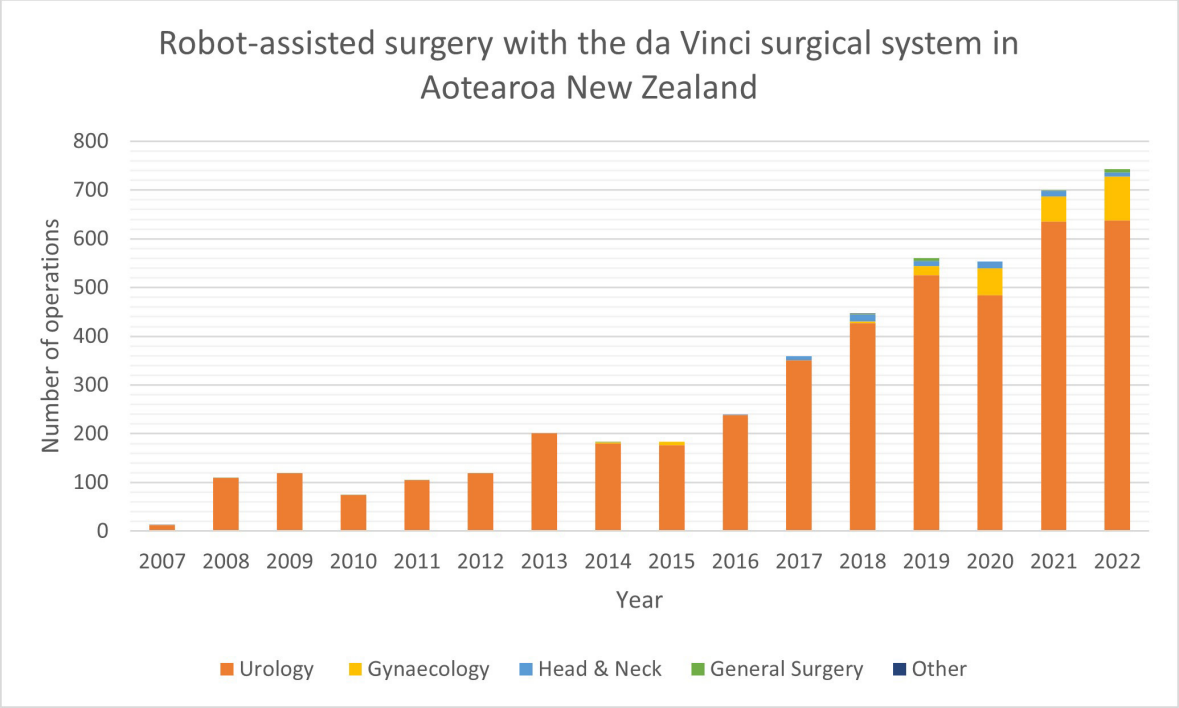

Table 1: Total number and proportion of robot-assisted surgeries utilising the da Vinci Surgical System in Aotearoa New Zealand, and the overall five most prevalent procedures.

Category	Numbers (% of total)		Most prevalent procedures	Numbers (% of category)
Urology	4,398 (93.4)		Prostatectomy	4,178 (95.0)
Gynaecology	227 (4.8)		Partial nephrectomy	161 (3.7)
Head and neck	67 (1.4)		Hysterectomy	152 (70.0)
General surgery	16 (0.3)		Tongue base resection	38 (56.7)
			Radical tonsillectomy	28 (41.8)

Table 2: Annual total number of cases using the da Vinci Surgical System and number of systems in operation in Australia and Aotearoa New Zealand.

Year	Cases, Australia	Cases, Aotearoa New Zealand	Systems, Australia	Systems, Aotearoa New Zealand
2015	6,726	183	34	2
2016	7,441	240	44	3
2017	8,818	359	48	3
2018	10,976	447	59	3
2019	13,625	560	65	4
2020	13,931	553	67	5

Status and current evidence on robot-assisted general surgery

The robot-assisted approach has been applied for almost all procedures in general surgery (colorectal,[7] oesophagogastric,[8] hepatopancreatobiliary,[9] breast,[10] endocrine,[11] hernia[12] and transplant[13]). The diversity of procedures in general surgery and the well-established role of laparoscopy as a minimal access technique for common procedures have resulted in RAS only comprising a relatively small proportion of all general surgery procedures despite the significant rate of growth. For example, in the US state of Michigan, the proportion of RAS for general surgery increased from 1.8% in 2012 to 15.1% in 2018, with RAS comprising 7.5% of all cholecystectomies in 2018.[14] At US community hospitals, which make up almost 90% of all general surgical RAS using the dVSS, it is estimated that about two general surgery procedures were done per dVSS per week in 2021.[15]

While the feasibility, safety and efficacy of RAS for numerous general surgery procedures have been demonstrated, contemporary evidence comparing its efficacy against the next best alternative (laparoscopic or open surgery) in randomised controlled trials (RCTs) is only recently emerging.[16] These suggest the value of robotic assistance for surgical procedures manifests in complex procedures, wherein conventional laparoscopy as the other alternative to the minimally invasive approach is technically challenging or inexpedient. For example, in the largest (n=1,171) and most recent multi-centre (11 hospitals) RCT, total mesorectal excision for rectal cancer using RAS compared with laparoscopic surgery resulted in significantly reduced intra- (5.5% vs 8.7%) and post-operative (16.2% vs 23.1%) complications, fewer conversions to open surgery (1.7% vs 3.9%), shorter length of stay (7 vs 8 days) and better oncological quality of resection.[7] Similar improvements in post-operative complications (13.2% vs 23.7%), open conversion (0% vs 2.9%) and post-operative length of stay (5 vs 7 days) have been observed in RAS compared with laparoscopy for abdominoperineal resections for low rectal cancer in a single-centre RCT (n=347), with additional improvements in 30-day readmission rate (2.3% vs 6.9%) and in urinary and sexual function without a difference in long-term oncological outcomes.[17] A lower rate of post-operative complications was also observed in gastric cancer comparing RAS with laparoscopy for gastrectomy (8.5% vs 19.3%, two-centre RCT, n=236)[18] and distal gastrectomy (9.2% and 17.6%, single-centre RCT, n=283).[19] Further RCTs comparing RAS with thoracolaparoscopic oesophagectomy for oesophageal cancer[8,20] and RAS with open pancreaticoduodenectomy for pancreatic and periampullary tumours[21,22] are ongoing.

Well-designed and conducted multi-centre RCTs provide the highest level of evidence regarding the efficacy of surgical therapeutic interventions.[23] Such trials are difficult to complete, with numerous challenges well described.[24] Although many established surgical procedures are not underpinned by multi-centre RCTs (for example, appendicectomy for uncomplicated acute appendicitis[25] and laparoscopic cholecystectomy[26]), its value has been highlighted by a multi-centre RCT comparing minimally invasive to open radical hysterectomy for early cervical cancer.[27] Those results in

gynaecologic oncology contravened the other retrospective and non-randomised evidence at the time to show an increased risk of death and recurrence with minimally invasive radical hysterectomy. The decreased overall survival in cervical cancer associated with RAS compared to open radical hysterectomy has since been corroborated in a recent systematic review and meta-analysis of matched or adjusted studies.[28]

In addition to the general considerations of the applicability of trial populations (e.g., rates of obesity and comorbidities), a special consideration of trials involving surgical procedures is that the results are significantly influenced by the surgeons' performance of the procedure.[29] The concept of a learning curve for surgical procedures is well recognised, but how to define and measure it for a specific procedure is variably established, let alone for a specific surgeon.[30] When comparing new surgical procedures with an established alternative there is a risk that trials earlier in the learning curve may not represent its true effectiveness, as was the case for laparoscopic inguinal hernia repair.[31]

The current literature reveals a significant monetary cost associated with RAS, especially in the context of a monopolistic RSS vendor.[16] Despite the recent and future introduction of numerous other RSS vendors to the market[1] it is extremely unlikely that the direct costs of RAS will be lower than laparoscopic or open surgery due to the requirement of extra equipment to enable robotic assistance. It is very seldom that an advancement in technology, whether in telecommunications, homeware or medical devices, is associated with a reduction in direct equipment costs. Hence, RAS must demonstrate robust clinical benefits to be determined cost effective. Evidence from multi-centre RCTs suggested no clinical benefits for less complex procedures such as inguinal[12] and simple ventral hernia[32] repair compared with laparoscopy, and instead demonstrated increased operative time, healthcare costs and surgeon frustration.

Cost effectiveness is an important consideration encompassed in assessing the value of an intervention. All healthcare systems, including our own, will continue to face multiple demands in weighing up investment opportunity costs. In addition to the possible clinical benefits pertaining to complex surgical procedures previously evidenced, we believe the value of RAS in the public healthcare system will manifest through engendering equitable access, quality improvement and workforce development to futureproof surgical care for our population.

The value of robot-assisted general surgery in the Aotearoa New Zealand context

As new RSS vendors enter the market, it is salient to note that Aotearoa New Zealand does not have a pre-market approval process for medical devices under the *Medicine Act 1981*. RSS are multi-speciality technology that facilitate diverse procedures and indications. Specialists must consider the value of a specific procedure for a specific patient in their hands with the best available evidence. For instance, robot-assisted cholecystectomy may provide superior outcomes for certain indications (e.g., Mirizzi syndrome) and populations (e.g., chronic liver disease), which are not amenable to RCTs, by an experienced RAS surgeon.[33] Therefore, the assessment of the value of RSS for the health system is perhaps more complex than a particular medical device designed for a specifically defined indication.

Value assessments must also incorporate a focus on equity rather than a singular focus on cost effectiveness, as interventions that reduce inequity of health outcomes may cost more but be more valuable. Private healthcare in Aotearoa New Zealand is following regional and global trends in RAS, with an established practice in urology and a nascent practice in gynaecology. Most recent available figures show robot-assisted radical prostatectomy for prostate cancer comprised 28% of all radical prostatectomies in Aotearoa New Zealand for the 2019/2020 year, compared to only 11% in 2010/2011.[34] General surgery in Aotearoa New Zealand appears to be on the precipice, and international experience suggests that it is not only the fastest-growing category but also the highest volume. Until recently, access to RAS has only been available via private healthcare through the ability to pay and through having private health insurance. That inevitability results in disparities in access by wealth, and only 38% of the population report being covered by private health insurance.[35] This disproportionally affects Māori and Pacific peoples, who have an average annual household equivalised disposable income of 16–21% ($9,000–$12,000) less than NZ Europeans[36] and lower rates of private health insurance—22% of Māori and 17% of Pacific peoples compared to 40% of NZ European/Other.[35] The implementation of robot-assisted general surgery in the public

healthcare system at the current opportunity, when it is not prevalent in private healthcare, may mitigate against disparities in access seen in other specialities.

Robot-assisted general surgery may also promote health equity by improving outcomes related to patient and disease-specific factors. For example, one of the Te Aho o Te Kahu quality improvement indicators for rectal cancer is the rate of abdominoperineal resection, which is associated with the rate of permanent stomas.[37] Māori have a higher rate than NZ European/Other (25.5% vs 21.9%),[37] and evidence from the most recent multi-centre RCT comparing RAS to laparoscopy for middle and low rectal cancer suggests a significantly lower rate for RAS (16.9% vs 22.7%).[7] In addition, the benefits of RAS for gastric cancer[18,19] are particularly relevant for Māori, for whom it is the fourth most common cause of cancer death, and, compared with NZ European/Other, have a higher age–sex-standardised incidence and are more likely to be diagnosed with local and regional disease amenable to surgery.[38,39] Thus, the implementation of robot-assisted general surgery in public hospitals aligns with the New Zealand Health Strategy's vision of pae ora, a healthy future for all, in "*harnessing the benefits of innovation, technology and practice that improves how care is delivered, reduces variation and tackles inequity in outcomes. … and support[ing] access for the most under-served communities*".[40]

What role Pharmac may have in determining the availability of RSS in public hospitals as it establishes a national list of all hospital medical devices by 2025 is yet to be defined. Traditional health technology assessments have been shown to be inadequate when exploring the context of application, such as patient-related and socio-organisational factors.[41] Therefore, there is also an imperative for clinicians to lead and be involved in the evaluation to generate evidence specific to the Aotearoa New Zealand context. Such are the limitations of the currently presented and available data, devoid of clinical characteristics.

There are also benefits that extend to education, training and quality assurance, some of which did not exist with open or laparoscopic surgery. It has been shown that early surgical trainees perform more competently with RAS than with laparoscopic surgery,[42] and for surgeons performing complex oncological surgery the RAS learning curve may be less than open surgery for achieving adequate cancer control.[43] This is germane to the Aotearoa New Zealand context due to our relatively small population; we could be considered a low-volume country for many complex surgical procedures.[44] The advances in simulation, proficiency-based curricula coupled with artificial intelligence and novel feedback mechanisms have improved safety and outcome for patients.[45–47] This has particular implications for Aotearoa New Zealand's public healthcare system, where patients do not usually have a choice of hospital or surgeon, and consumers have emphasised the importance of ensuring professional competence that is publicly demonstrated.[48]

Furthermore, the provision of RAS in public hospitals is a prudent strategic investment in developing a skilled workforce capable of delivering high-quality care, a priority area in the New Zealand Health Strategy.[40] As the evidence on RAS matures it is likely that Aotearoa New Zealand will follow the trends of other advanced economies overseas that are increasingly utilising RAS for complex surgical oncology.[3,49,50] General surgery training predominantly takes place in public hospitals, where the only accredited training attachments are based. RAS in public hospitals provides equitable opportunities to upskill current advanced trainees for competitive overseas fellowships at academic centres, where RAS is increasingly used. It will also support the recruitment and retention of returning specialists to the public health system, where they may apply their expertise in advanced therapies for the benefit of our local populations and contribute to the education of colleagues, including trainees. This will build capacity to integrate RAS into the training curriculum and ultimately develop self-sufficient pathways for local trainees in the Aotearoa New Zealand context. At Te Whatu Ora – Health New Zealand's Waitematā District we partnered with several stakeholders to deliver free minimally invasive surgery workshops for surgeons and trainees that involved laparoscopic box trainers, ex-vivo animal organ simulation and RAS training, including the use of virtual reality.

Frameworks in place to support ethical implementation in Aotearoa New Zealand

In addition to equity of access and outcomes discussed above, the adoption of RAS necessitates other ethical considerations regarding informed consent, biases and managing conflicts of interest, including advertising. Aotearoa New Zealand law (*Health and Disability Commissioner Act 1994* and

the *Health and Disability Commissioner [Code of Health and Disability Services Consumers' Rights] Regulations 1996*) and the Commissioner's decisions provide clear guidance on informed consent for innovative procedures.[51–53] Several cognitive and emotional biases exist when handling medical technology.[54] It is important to be aware of biases as they can influence clinical practice and patient outcomes.[55,56] An essential component of addressing biases is mitigating the effect of conflicts of interest.[57] The Royal Australasian College of Surgeons provides practical guidance in a position paper on interactions with the medical industry.[58] Te Kaunihera Rata o Aotearoa | Medical Council of New Zealand have a statement on advertising that sets a standard supported by the *Fair Trading Act 1986*.[59]

At Te Whatu Ora – Waitematā District we have established a transdisciplinary committee of multi-speciality clinicians, hospital management and non-clinical representation that guides the implementation of RAS in line with suggested evidence-based practice.[60] We have also developed an independent credentialing process that recognises individual surgeon performance is context specific and is not necessarily portable from one setting to another.[61]

Conclusion

The introduction of RAS to general surgery in Aotearoa New Zealand has some parallels to the introduction of laparoscopy over two decades ago.[62] Current evidence suggests that its value for patients is realised in complex procedures, and its value for the health system may be multifaceted. To achieve optimal outcomes, educational and quality improvement initiatives should be embedded in clinical implementation. Aotearoa New Zealand is well placed with legal, ethical and professional frameworks to support evidence-based dissemination. Clinicians from multiple specialities within general surgery, along with patients, should be involved in defining the future role of robot-assisted general surgery in Aotearoa New Zealand.

COMPETING INTERESTS
The authors declare no conflicts of interest. None of the authors have received any payment from Intuitive Surgical, Device Technologies or any of their subsidiaries.

ACKNOWLEDGEMENTS
Phillip Chao is the recipient of a Health Research Council of New Zealand (HRC) Clinical Research Training Fellowship (reference number: 22/034). The authors thank Device Technologies, Auckland for providing the data without cost or restrictions. The HRC, Device Technologies and Te Whatu Ora – Waitematā District had no role in the preparation of or decision to submit the manuscript. The views and opinions expressed in this manuscript are those of the authors and do not necessarily reflect the HRC, Device Technologies or Te Whatu Ora – Waitematā District.

AUTHOR INFORMATION
Phillip P Chao: Research Fellow, Department of Surgery, Faculty of Medical and Health Sciences, The University of Auckland, Auckland; General Surgery Trainee, Department of General Surgery, Te Whatu Ora – Waitematā District, Auckland.
Jonathan B Koea: Professor, Department of Surgery and Te Kupenga Hauora Māori, Faculty of Medical and Health Sciences, The University of Auckland, Auckland; Hepatobiliary and General Surgeon, Department of General Surgery, Te Whatu Ora – Waitematā District, Auckland.
Andrew G Hill: Professor, Department of Surgery, Faculty of Medical and Health Sciences, The University of Auckland, Auckland.
David Resoli: General Manager, Surgery & Ambulatory Services, Te Whatu Ora – Waitematā District, Auckland.
Sanket Srinivasa: Senior Lecturer, Department of Surgery, Faculty of Medical and Health Sciences, The University of Auckland, Auckland; Hepatopancreatobiliary and General Surgeon, Department of General Surgery, Te Whatu Ora – Waitematā District, Auckland.

CORRESPONDING AUTHOR
Phillip Chao: Department of Surgery, Faculty of Medical and Health Sciences, The University of Auckland, Auckland. E: phillip.chao@waitematadhb.govt.nz

REFERENCES
1. Klodmann J, Schlenk C, Hellings-Kuß A, et al. An Introduction to Robotically Assisted Surgical Systems: Current Developments and Focus Areas of Research. Curr Robot Rep. 2021;2:321-32. https://doi.org/10.1007/s43154-021-00064-3.
2. Wilson LC, Pickford JE, Gilling PJ. Robot-assisted laparoscopic radical prostatectomy (RALP)--a new surgical treatment for cancer of the prostate. N Z Med J. 2008;121(1287):32-8.
3. Larach JT, Flynn J, Kong J, et al. Robotic colorectal surgery in Australia: evolution over a decade. ANZ J Surg. 2021;91(11):2330-2336. doi: 10.1111/ans.16554.
4. Cameron-Jeffs R, Yong C, Carey M. Robotic-assisted gynaecological surgery in Australia: current trends, challenges and future possibility. ANZ J Surg. 2021;91(11):2246-2249. doi: 10.1111/ans.17292.
5. Furrer MA, Costello DM, Thomas BC, et al. Robotics in Australian urology contemporary practice and future perspectives. ANZ J Surg. 2021;91(11):2241-2245. doi: 10.1111/ans.17161.
6. Guthart G. J.P. Morgan Healthcare Conference 2023. 41st Annual JP Morgan Healthcare Conference. 2023 Jan 9-12. San Franciso, California: Intuitive.
7. Feng Q, Yuan W, Li T, et al. Robotic versus laparoscopic surgery for middle and low rectal cancer (REAL): short-term outcomes of a multicentre randomised controlled trial. Lancet Gastroenterol Hepatol. 2022;7(11):991-1004. doi: 10.1016/S2468-1253(22)00248-5.
8. Yang Y, Li B, Yi J, et al. Robot-assisted Versus Conventional Minimally Invasive Esophagectomy for Resectable Esophageal Squamous Cell Carcinoma: Early Results of a Multicenter Randomized Controlled Trial: the RAMIE Trial. Ann Surg. 2022;275(4):646-53. doi: 10.1097/SLA.0000000000005023.
9. Chen S, Zhan Q, Jin JB, et al. Robot-assisted laparoscopic versus open middle pancreatectomy: short-term results of a randomized controlled trial. Surg Endosc. 2017;31(2):962-71. doi: 10.1007/s00464-016-5046-z.
10. Toesca A, Sangalli C, Maisonneuve P, et al. A Randomized Trial of Robotic Mastectomy Versus Open Surgery in Women With Breast Cancer or BrCA Mutation. Ann Surg. 2022;276(1):11-19. doi: 10.1097/SLA.0000000000004969.
11. Ma W, Mao Y, Zhuo R, et al. Surgical outcomes of a randomized controlled trial compared robotic versus laparoscopic adrenalectomy for pheochromocytoma. Eur J Surg Oncol. 2020;46(10 Pt A):1843-1847. doi: 10.1016/j.ejso.2020.04.001.
12. Prabhu AS, Carbonell A, Hope W, et al. Robotic Inguinal vs Transabdominal Laparoscopic Inguinal Hernia Repair: The RIVAL Randomized Clinical Trial. JAMA Surg. 2020;155(5):380-7. doi: 10.1001/jamasurg.2020.0034.
13. Bhattu AS, Ganpule A, Sabnis RB, et al. Robot-Assisted Laparoscopic Donor Nephrectomy vs

Standard Laparoscopic Donor Nephrectomy: A Prospective Randomized Comparative Study. J Endourol. 2015;29(12):1334-40. doi: 10.1089/end.2015.0213.
14. Sheetz KH, Claflin J, Dimick JB. Trends in the Adoption of Robotic Surgery for Common Surgical Procedures. JAMA Netw Open. 2020;3(1):e1918911. doi: 10.1001/jamanetworkopen.2019.18911.
15. Mills J, Liebert C, Wren SM, et al. Robotic General Surgery Trends in the Veterans Health Administration, Community Practice, and Academic Centers From 2013 to 2021. JAMA Surg. 2023;158(5):552-4. doi: 10.1001/jamasurg.2022.7728.
16. Dhanani NH, Olavarria OA, Bernardi K, et al. The Evidence Behind Robot-Assisted Abdominopelvic Surgery : A Systematic Review. Ann Intern Med. 2021;174(8):1110-7. doi: 10.7326/M20-7006.
17. Feng Q, Tang W, Zhang Z, et al. Robotic versus laparoscopic abdominoperineal resections for low rectal cancer: A single-center randomized controlled trial. J Surg Oncol. 2022;126(8):1481-93. doi: 10.1002/jso.27076.
18. Ojima T, Nakamura M, Hayata K, et al. Short-term Outcomes of Robotic Gastrectomy vs Laparoscopic Gastrectomy for Patients With Gastric Cancer: A Randomized Clinical Trial. JAMA Surg. 2021;156(10):954-63. doi: 10.1001/jamasurg.2021.3182.
19. Lu J, Zheng CH, Xu BB, et al. Assessment of Robotic Versus Laparoscopic Distal Gastrectomy for Gastric Cancer: A Randomized Controlled Trial. Ann Surg. 2021;273(5):858-67. doi: 10.1097/SLA.0000000000004466.
20. Tagkalos E, van der Sluis PC, Berlth F, et al. Robot-assisted minimally invasive thoraco-laparoscopic esophagectomy versus minimally invasive esophagectomy for resectable esophageal adenocarcinoma, a randomized controlled trial (ROBOT-2 trial). BMC Cancer. 2021;21(1):1060. doi: 10.1186/s12885-021-08780-x.
21. Jin J, Shi Y, Chen M, et al. Robotic versus Open Pancreatoduodenectomy for Pancreatic and Periampullary Tumors (PORTAL): a study protocol for a multicenter phase III non-inferiority randomized controlled trial. Trials. 2021;22(1):954. doi: 10.1186/s13063-021-05939-6.
22. Klotz R, Dörr-Harim C, Bruckner T, et al. Evaluation of robotic versus open partial pancreatoduodenectomy-study protocol for a randomised controlled pilot trial (EUROPA, DRKS00020407). Trials. 2021;22(1):40. doi: 10.1186/s13063-020-04933-8.
23. Hirst A, Philippou Y, Blazeby J, et al. No Surgical Innovation Without Evaluation: Evolution and Further Development of the IDEAL Framework and Recommendations. Ann Surg. 2019;269(2):211-20. doi: 10.1097/SLA.0000000000002794.
24. Cook JA. The challenges faced in the design, conduct and analysis of surgical randomised controlled trials. Trials. 2009;10:9. doi: 10.1186/1745-6215-10-9.
25. de Almeida Leite RM, Seo DJ, Gomez-Eslava B, et al. Nonoperative vs Operative Management of Uncomplicated Acute Appendicitis: A Systematic Review and Meta-analysis. JAMA Surg. 2022;157(9):828-34. doi: 10.1001/jamasurg.2022.2937.
26. Zhao JJ, Syn NL, Chong C, et al. Comparative outcomes of needlescopic, single-incision laparoscopic, standard laparoscopic, mini-laparotomy, and open cholecystectomy: A systematic review and network meta-analysis of 96 randomized controlled trials with 11,083 patients. Surgery. 2021;170(4):994-1003. doi: 10.1016/j.surg.2021.04.004.
27. Ramirez PT, Frumovitz M, Pareja R, et al. Minimally Invasive versus Abdominal Radical Hysterectomy for Cervical Cancer. N Engl J Med. 2018;379(20):1895-904. doi: 10.1056/NEJMoa1806395.
28. Leitao MM, Jr, Kreaden US, Laudone V, et al. The RECOURSE Study: Long-term Oncologic Outcomes Associated With Robotically Assisted Minimally Invasive Procedures for Endometrial, Cervical, Colorectal, Lung, or Prostate Cancer: A Systematic Review and Meta-analysis. Ann Surg. 2023;277(3):387-96. doi: 10.1097/SLA.0000000000005698.
29. Corrigan N, Marshall H, Croft J, et al. Exploring and adjusting for potential learning effects in ROLARR: a randomised controlled trial comparing robotic-assisted vs. standard laparoscopic surgery for rectal cancer resection. Trials. 2018;19(1):339. doi: 10.1186/s13063-018-2726-0.
30. Soomro NA, Hashimoto DA, Porteous AJ, et al. Systematic review of learning curves in robot-assisted surgery. BJS Open. 2020;4(1):27-44. doi: 10.1002/bjs5.50235.
31. Aiolfi A, Cavalli M, Ferraro SD, et al. Treatment of Inguinal Hernia: Systematic Review and Updated Network Meta-analysis of Randomized Controlled Trials. Ann Surg. 2021;274(6):954-61. doi: 10.1097/SLA.0000000000004735.
32. Olavarria OA, Bernardi K, Shah SK, et al. Robotic versus laparoscopic ventral hernia repair: multicenter, blinded randomized controlled trial. BMJ. 2020;370:m2457. doi: 10.1136/bmj.m2457.
33. Chandhok S, Chao P, Koea J, Srinivasa S. Robotic-

assisted cholecystectomy: Current status and future application. Laparosc Endosc Robot Surg. 2022;5(3):85-91. https://doi.org/10.1016/j.lers.2022.06.002.
34. Chao PP, Koea JB, Zargar-Shoshtari K. Robot-assisted radical prostatectomy in Aotearoa New Zealand: equity, quality, and workforce. ANZ J Surg. 2023. https://doi.org/10.1111/ans.18740.
35. Manatū Hauora – Ministry of Health. Annual Data Explorer: New Zealand Health Survey [Internet]. [cited 2023 Jul 20.] Available from: https://minhealthnz.shinyapps.io/nz-health-survey-2021-22-annual-data-explorer/.
36. Stats New Zealand | Tatauranga Aotearoa. Household income and housing-cost statistics: Year ended June 2022 [Internet]. 2023 Mar 23 [cited 2023 Jul 20]. Available from: https://www.stats.govt.nz/information-releases/household-income-and-housing-cost-statistics-year-ended-june-2022.
37. Te Aho o Te Kahu – Cancer Control Agency. Bowel Cancer Quality Improvement Monitoring Report Update: Updated using 2017–2019 data. Wellington, New Zealand: Te Aho o Te Kahu; 2022 [cited 2023 Jul 20]. Available from: https://hcmsitesstorage.blob.core.windows.net/cca/assets/Bowel_Cancer_Quality_Improvement_Monitoring_Report_Update_050422_edb7a438d5.pdf.
38. Gurney J, Stanley J, Jackson C, Sarfati D. Stage at diagnosis for Māori cancer patients: disparities, similarities and data limitations. N Z Med J. 2020;133(1508):43-64.
39. Gurney JK, Robson B, Koea J, et al. The most commonly diagnosed and most common causes of cancer death for Māori New Zealanders. N Z Med J. 2020;133(1521):77-96.
40. Manatū Hauora – Ministry of Health. New Zealand Health Strategy [Internet]. Wellington, New Zealand: Manatū Hauora – Ministry of Health; 2023 [cited 2023 Jul 20]. Available from: https://www.health.govt.nz/publication/new-zealand-health-strategy.
41. Abrishami P, Boer A, Horstman K. How can we assess the value of complex medical innovations in practice? Expert Rev Pharmacoecon Outcomes Res. 2015;15(3):369-71. doi: 10.1586/14737167.2015.1037834.
42. Gall TMH, Alrawashdeh W, Soomro N, et al. Shortening surgical training through robotics: randomized clinical trial of laparoscopic versus robotic surgical learning curves. BJS Open. 2020;4(6):1100-1108. doi: 10.1002/bjs5.50353.
43. Bravi CA, Dell'Oglio P, Mazzone E, et al. The Surgical Learning Curve for Biochemical Recurrence After Robot-assisted Radical Prostatectomy. Eur Urol Oncol. 2023;6(4):414-421. doi: 10.1016/j.euo.2022.06.010.
44. Chao PP, Koea JB, Hill AG, Srinivasa S. Measures to Achieve Quality in Minimally Invasive Hepato-Pancreato-Biliary (HPB) Surgery. Ann Surg Open. 2023;4(1):e232. doi: 10.1097/AS9.0000000000000232.
45. Cathcart P, Sridhara A, Ramachandran N, et al. Achieving Quality Assurance of Prostate Cancer Surgery During Reorganisation of Cancer Services. Eur Urol. 2015;68(1):22-9. doi: 10.1016/j.eururo.2015.02.028.
46. Tam V, Zenati M, Novak S, et al. Robotic Pancreatoduodenectomy Biotissue Curriculum has Validity and Improves Technical Performance for Surgical Oncology Fellows. J Surg Educ. 2017;74(6):1057-65. doi: 10.1016/j.jsurg.2017.05.016.
47. Hung AJ, Liu Y, Anandkumar A. Deep Learning to Automate Technical Skills Assessment in Robotic Surgery. JAMA Surg. 2021;156(11):1059-60. doi: 10.1001/jamasurg.2021.3651.
48. Hamblin R, Shuker C, Stolarek I, Wilson J, Merry AF. Public reporting of health care performance data: what we know and what we should do. N Z Med J. 2016;129(1431):7-17.
49. Davis CH, Grandhi MS, Gazivoda VP, et al. Robotic pancreatoduodenectomy: trends in technique and training challenges. Surg Endosc. 2023;37(1):266-73. doi: 10.1007/s00464-022-09469-3.
50. Hajirawala LN, Leonardi C, Orangio GR, et al. Trends in Open, Laparoscopic, and Robotic Approaches to Colorectal Operations. Am Surg. 2023; 89:2129-31.
51. Health and Disability Commissioner. Gastrointestinal and Hepatobiliary Surgeon, Professor Richard Stubbs: A Report by the Health and Disability Commissioner. 2010. Case 09HDC01870.
52. Health and Disability Commissioner. District Health Board (now Te Whatu Ora) Obstetrician & Gynaecologist, Dr C: A Report by the Deputy Health and Disability Commissioner. 2022. Case 19HDC01509.
53. Health and Disability Commissioner. Informed consent to innovative surgery. 2009. Case 08HDC20258.
54. Hofmann B. Biases and imperatives in handling medical technology. Health Policy Technol. 2019;8(4):377-85. doi: 10.1016/j.hlpt.2019.10.005
55. Scherr KA, Fagerlin A, Wei JT, et al. Treatment Availability Influences Physicians' Portrayal of Robotic Surgery During Clinical Appointments. Health Commun. 2017;32(1):119-25. doi: 10.1080/10410236.2015.1099502.
56. Kiani S, Kurian D, Henkin S, et al. Direct to

consumer advertising of robotic heart bypass surgery: effectiveness, patient satisfaction and clinical outcomes. Int J Pharm Healthc Mark. 2016;10(4):358-75. doi: 10.1108/IJPHM-05-2015-0016.
57. Johnson J, Hutchison K. They Know How to Work It, That's Their Focus in Life: The Complex Role of Industry Representatives in Surgical Innovation. J Empir Res Hum Res Ethics. 2018;13(5):461-74. doi: 10.1177/1556264618785037.
58. Royal Australasian College of Surgeons. Interactions with the medical industry (2021) [Internet]. 2021 [cited 2023 May 18]. Available from: https://www.surgeons.org/en/about-racs/position-papers/interactions-with-the-medical-industry-2021.
59. Te Kaunihera Rata o Aotearoa | Medical Council of New Zealand. Advertising [Internet]. Wellington, New Zealand: Te Kaunihera Ratao Aotearoa | Medical Council of New Zealand; 2022 [cited 2023 May 10]. Available from: https://hcmsitesstorage.blob.core.windows.net/cca/assets/Bowel_Cancer_Quality_Improvement_Monitoring_Report_Update_050422_edb7a438d5.pdf.
60. Gupta S, Muskens IS, Fandino LB, et al. Oversight in Surgical Innovation: A Response to Ethical Challenges. World J Surg. 2018;42(9):2773-2780. doi: 10.1007/s00268-018-4565-2.
61. Huckman RS, Pisano GP. The Firm Specificity of Individual Performance: Evidence from Cardiac Surgery. Manage Sci. 2006;52:473-88. doi: 10.1287/mnsc.1050.0464.
62. Poole G, Ooi S, Scott S, Frizelle F. How much has the introduction of laparoscopic surgery changed open surgery? N Z Med J. 2003;116(1178):U518.