

Perioperative anaesthetic management in robotic-assisted surgery: a bibliometric and visual analysis of two decades of research

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ABSTRACT

Aims: Robotic-assisted surgery imposes a distinctive combination of physiological conditions that define a specific anaesthetic problem: prolonged carbon dioxide pneumoperitoneum, fixed steep head-down positioning, and restricted access to the patient after docking. Bibliometric analyses of robotic surgery have been organised by surgical specialty, and none has mapped its anaesthetic and perioperative dimension. This study describes the structure, growth and thematic evolution of that literature.

Methods: The Web of Science Core Collection was searched for articles and reviews published in English between 2000 and 2025 combining robotic surgery terms with anaesthetic and perioperative terms. Retracted and duplicate records were removed and both authors independently reviewed all flagged records. Analyses were performed in R with the bibliometrix package and VOSviewer, after harmonising country names, affiliations and author keywords with purpose-built thesauri.

Results: The final corpus comprised 1,528 documents from 422 journals and 8,626 authors, attracting 20,985 citations (h-index 58). Output grew at 14.6% annually between 2010 and 2025, with 55.8% of the literature published in the last five years. The United States led output (567 documents), followed by the Republic of Korea (178). Yonsei University was the most productive institution (50 documents). International collaboration was limited (11.78%). The proportion of this literature appearing in anaesthesiology journals fell from 48.5% in 2001-2008 to 21.9% in 2021-2025. Five thematic clusters emerged; telesurgery and Artificial Intelligence were present only as low-frequency emerging topics.

Conclusion: This literature is expanding rapidly but is increasingly published outside anaesthesiology journals, with limited international collaboration.

Keywords: Anesthesiology, patient positioning, head-down tilt, pneumoperitoneum, publishing

INTRODUCTION

Robotic-assisted surgery imposes a set of physiological conditions that are unusual in their combination rather than in any single element. Carbon dioxide (CO₂) pneumoperitoneum is maintained for hours while the patient is held in a steep head-down tilt fixed by the docked manipulator arms, so that positioning cannot be adjusted once the operation is under way and physical access to the patient is substantially restricted.¹ The resulting increases in intra-abdominal and intrathoracic pressure reduce pulmonary compliance and functional residual capacity, while cephalad venous congestion raises intraocular and intracranial pressure and alters cerebral perfusion.²⁻⁴ These changes are not incidental to the surgical approach. They define the anaesthetic problem. Managing them has generated a distinct body of work on ventilation strategy, haemodynamic and fluid management, neuromuscular blockade, positioning-related injury and analgesic technique, alongside the enhanced recovery after surgery (ERAS) pathways and same-day discharge protocols that the minimally invasive approach has made feasible.⁵⁻⁷

Robotic platforms have meanwhile diffused rapidly across urology, gynaecology, general surgery and thoracic surgery, and the volume of associated publication has grown accordingly. This growth has attracted repeated bibliometric attention, but that attention has been organised almost entirely along surgical lines. Published analyses have mapped robotic surgery in obstetrics and gynaecology,⁸ in spinal⁹ and orthopaedic surgery,¹⁰ in acute care and trauma settings,¹¹ and from a health economics perspective.¹² Each characterises productivity, collaboration and thematic structure within a surgical specialty. Bibliometric work in anaesthesiology has developed in parallel but along topic lines, addressing Artificial Intelligence in anaesthetic practice,¹³ perioperative multimodal analgesia¹⁴ and perioperative complications.¹⁵ To our knowledge, no bibliometric analysis has been conducted at the intersection of these two literatures. None has mapped the anaesthetic and perioperative dimension of robotic surgery as a field in its own right.

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This omission matters for a reason that is itself empirical. If the perioperative agenda in robotic surgery is increasingly set outside anaesthesiology, then anaesthesiologists are contributing to a literature whose structure, leading venues and emerging directions they have not systematically examined. Bibliometric analysis is suited to this question because it describes the structure of a literature (its geography, its collaborative architecture, its journals, and the way its themes succeed one another) rather than pooling effect estimates as a systematic review would.¹⁶ It is therefore appropriate where the object of interest is the shape of a field rather than the answer to a single clinical question.

The present study maps the global literature on perioperative anaesthetic management in robotic-assisted surgery indexed in the Web of Science Core Collection between 2001 and 2025. Its objectives were to describe the growth trajectory and model its trend; to identify the leading countries, institutions, authors and journals and characterise international collaboration; to determine the distribution of this literature between anaesthesiology and surgical journals and how that distribution has changed; and to delineate the thematic structure of the field and the topics currently emerging.

METHODS

Ethics

As the study is based solely on previously published and publicly available bibliographic records, and does not involve human participants, animals, or identifiable patient data, neither institutional review board approval nor informed consent was required. The study was conducted in accordance with the relevant ethical principles and publication ethics standards.

Study Design

This is a bibliometric and visual analysis of the scientific literature on perioperative anaesthetic management in robotic-assisted surgery. Reporting follows the BIBLIO minimum requirements for bibliometric reviews of the biomedical literature,¹⁷ and the selection process is presented as a flow diagram (Figure 1).

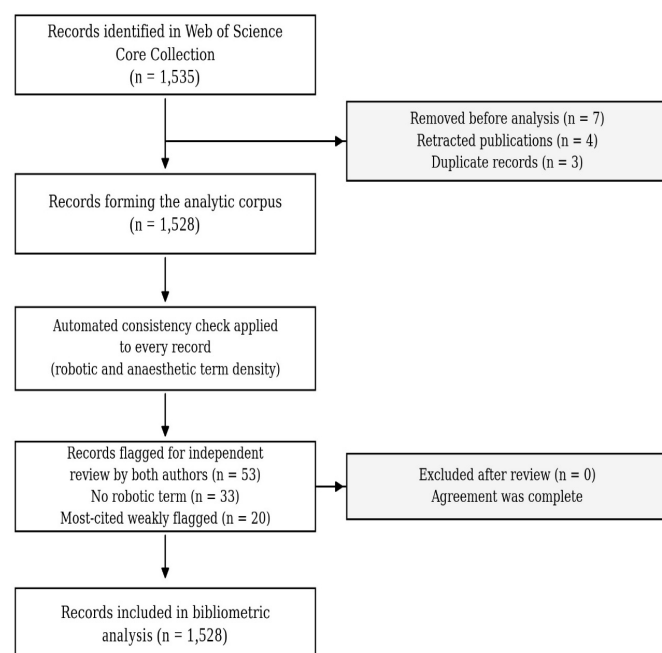


Figure 1. Flow diagram of record identification and selection

Data Source and Search Strategy

The Web of Science Core Collection (Clarivate Analytics, Philadelphia, PA, USA) was the single data source because it provides complete cited-reference data, a prerequisite for co-citation analysis. All records were retrieved on a single day, 1 August 2026, to avoid inconsistencies arising from weekly indexing updates.

A stratified search strategy was constructed. The first component captured robotic surgery through proximity operators combining the truncated term robot* with surgical procedure terms, together with named platforms (da Vinci, Hugo RAS, Versius, Senhance, Revo-i, hinotori) and the terms surgical robot*, telesurg* and telerobotic surg*. The second component captured anaesthetic and perioperative care and was deliberately stratified. Procedure-specific perioperative terms (for example pneumoperitoneum, Trendelenburg, sugammadex and erector spinae plane block) were searched in title, abstract and author keyword fields. Generic terms recurring incidentally in almost every surgical outcome report (for example an*esthe*, opioid* and postoperative pain) were restricted to title and author keyword fields. This stratification preserved sensitivity for anaesthesia-specific content while limiting retrieval of surgical papers in which anaesthesia is mentioned only in passing. A third component retrieved all robotic surgery records published in journals assigned to the Web of Science Anesthesiology category, capturing anaesthesia-focused work using none of the indexed keywords.

Results were limited to the document types Article and Review, to English, and to 2000-2025. The lower boundary corresponds to United States Food and Drug Administration approval of the da Vinci system in July 2000. The upper boundary was the last complete calendar year, avoiding an artefactual decline in the final data point.

Eligibility and Record Verification

Records were eligible if they addressed anaesthetic technique, perioperative management or the physiological consequences of the robotic operative setting in human patients. Retracted publications and duplicate records sharing a digital object identifier were removed before analysis, retaining the more highly cited copy of each duplicate pair.

Because the search was designed for specificity rather than breadth, an automated consistency check was applied to every remaining record. Records were flagged if robotic terms appeared neither in the title nor more than once across title, abstract and author keywords, or if anaesthetic terms appeared at most once. Both authors then independently reviewed all records containing no robotic mention (n=33) together with the twenty most-cited weakly flagged records. Agreement was complete and no record was excluded, so a chance-corrected agreement coefficient was not calculable.

Data Extraction and Normalisation

Records were exported as plain text including full records and cited references, and processed in R version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria)¹⁸ with the bibliometrix package.¹⁶ Four normalisation steps preceded analysis.

First, publication year was corrected. Web of Science filters and tabulates by Early Access date, whereas the exported

publication-year field carries the final issue year. In this corpus, 425 records carried an Early Access date and 113 of these disagreed with the issue year. The Early Access year was used when present, which reproduced the database interface counts exactly.

Second, country names were harmonised: Turkey and Türkiye were merged following the 2022 designation change, and England, Scotland, Wales and Northern Ireland were merged as the United Kingdom. Taiwan was retained as a separate entity, consistent with the database.

Third, institutional affiliations were merged, because Web of Science lists parent systems and their constituent units separately.

Fourth, author-level analyses used full author names rather than abbreviated forms, because abbreviated forms conflate distinct individuals in a corpus with substantial East Asian authorship. Author keywords were consolidated with a purpose-built thesaurus merging orthographic variants, abbreviations and synonyms.

Bibliometric Indicators and Visualisation

Annual output was modelled by exponential regression and summarised by the compound annual growth rate, defined as the ratio of the last to the first annual publication count raised to the power of the reciprocal of the number of intervening years, minus one. Two growth values are reported and they are not interchangeable. The annual growth rate given in [Table 1](#) is the bibliometrix default, which applies this formula to the full 2001-2025 timespan and therefore takes the single document published in 2001 as its baseline; with a denominator of one document the resulting value is highly sensitive to the choice of starting year. The compound annual growth rates given in the Results were recalculated over 2010-2025 and 2015-2025, intervals in which annual output was already established, and describe recent growth more informatively. Author productivity was tested against Lotka's law,¹⁹ its exponent estimated by ordinary least squares regression of log-transformed author counts on log-transformed document counts across all productivity levels, and journal distribution was tested against Bradford's law.²⁰ Country-level output is reported on two bases, which are not interchangeable. Overall country participation credits a document to every country represented among the affiliations of all its authors, so an internationally co-authored paper is counted once for each contributing country; these are the counts given in the text when total national contribution is described. Corresponding-author country assigns each document to the country of its corresponding author alone and is the basis of [Table 2](#) and of the collaboration indices. Collaboration was described using single-country and multiple-country publication proportions, which are defined only under corresponding-author attribution. Networks were constructed in bibliometrix and visualised with the Fruchterman-Reingold layout and Louvain clustering (random seed fixed at 42 for keywords and 7 for countries); VOSviewer version 1.6.20 (Centre for Science and Technology Studies, Leiden University, Leiden, the Netherlands) was used for cross-validation.²¹ Analyses were descriptive. No inferential hypothesis testing was performed.

Table 1. Main information about the corpus

Item	Value
Timespan	2001-2025
Documents	1,528
Sources (journals)	422
Original articles	1,324
Reviews	204
Annual growth rate (%)	24.52
Mean document age (years)	6.07
Total citations	20,985
Mean citations per document	13.73
Documents never cited (%)	10.3
Corpus h-Index	58
Corpus g-Index	83
Cited references	46,120
Authors	8,626
Author appearances	10,351
Single-authored documents	31
Co-authors per document	6.77
Documents per author	0.177
International co-authorship (%)	11.78
Author keywords	2,811
Keywords plus	2,306
Open access documents (%)	53.4
Author counts are based on full author names after disambiguation of abbreviated forms. The annual growth rate is the bibliometrix default compound annual growth rate, calculated across the full 2001-2025 timespan from the first and last annual counts of 1 and 193 documents. Because the 2001 baseline is a single document, this value exceeds the compound annual growth rates of 14.6% for 2010-2025 and 11.0% for 2015-2025 reported in the text	

Table 2. Ten most productive countries, ranked by corresponding-author country

Country	Documents	Total citations	SCP	MCP	Mean citations	MCP ratio (%)
USA	528	8,144	467	61	15.42	11.6
Republic of Korea	171	2,507	163	8	14.66	4.7
China	128	961	123	5	7.51	3.9
Japan	123	1,125	122	1	9.15	0.8
Italy	80	1,075	65	15	13.44	18.8
India	75	552	73	2	7.36	2.7
United Kingdom	51	781	44	7	15.31	13.7
Germany	46	886	37	9	19.26	19.6
Türkiye	45	197	42	3	4.38	6.7
France	42	663	33	9	15.79	21.4
Each document is assigned to the country of its corresponding author, so these counts are lower than the overall country participation figures given in the Results, which credit a document to every country represented among its authors' affiliations. Turkey and Türkiye were merged, as were England, Scotland, Wales and Northern Ireland. SCP: Single-country publications, MCP: Multiple-country publications						

RESULTS

Selection and Characteristics of the Corpus

The search retrieved 1,535 records. Four retracted publications and three duplicate records were removed, leaving 1,528 documents for analysis. Independent review of flagged records excluded none ([Figure 1](#)).

The corpus spanned 2001 to 2025 and comprised 1,324 original articles and 204 reviews published across 422 journals

by 8,626 authors (Table 1). Documents carried a mean of 6.77 co-authors and only 31 were single-authored, indicating a collaboratively produced literature. The corpus attracted 20,985 citations, a mean of 13.73 per document, with a corpus h-index of 58 and a g-index of 83. In total, 10.3% of documents had never been cited. Just over half (53.4%) were open access.

Growth Trajectory

Output was negligible for almost a decade after the first record appeared in 2001, with 33 documents published between 2001 and 2008 (Figure 2). A period of emergence between 2009 and 2016 produced 290 documents as the physiological consequences of the robotic operative setting were first characterised. Acceleration followed: annual output rose from 71 documents in 2018 to 193 in 2025, and the years 2021 to 2025 alone contributed 852 documents, or 55.8% of the corpus. The compound annual growth rate was 14.6% between 2010 and 2025 and 11.0% between 2015 and 2025. An exponential model fitted the post-2009 trajectory closely ($R^2=0.951$) and projects approximately 282 publications in 2026 and 391 in 2028 if current conditions persist.

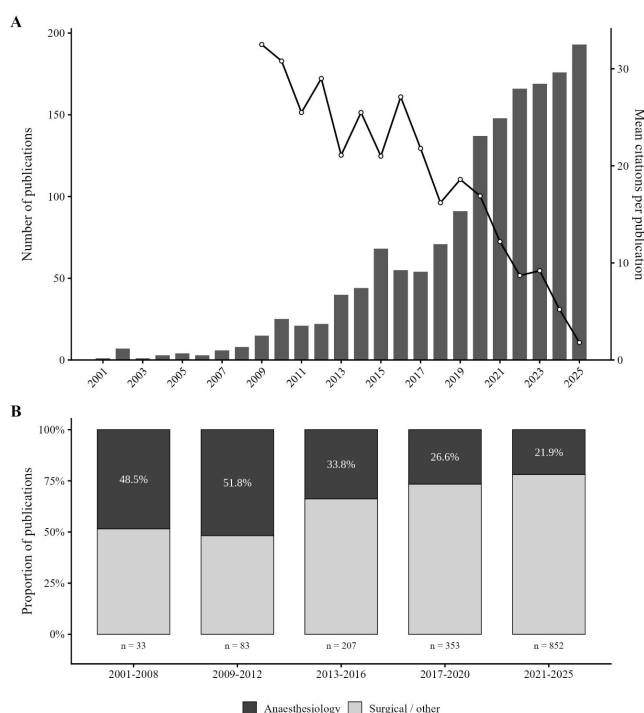


Figure 2. Growth and journal distribution of the literature, 2001-2025. (A) Annual number of publications (bars, left axis) and mean citations per publication (line, right axis). The citation line is shown only for years with at least fifteen publications; its decline in recent years reflects citation lag rather than reduced influence. (B) Proportion of publications appearing in anaesthesiology versus surgical or other journals, by period. Percentages denote the anaesthesiology share

Mean citations per document declined from 32.5 in 2009 to 1.8 in 2025. This gradient reflects citation lag rather than diminishing influence, since recent publications have had proportionately less time to accrue citations.

Countries, Institutions and Collaboration

Authors from 63 countries contributed. Counting every country represented among author affiliations, the United States dominated with 567 documents, more than three times the second-ranked country. The Republic of Korea followed with 178 documents, ahead of China (135), Japan (125) and Italy (111). Türkiye ranked tenth with 52 documents. The corresponding-author counts in Table 2 are lower for the

same countries, at 528 documents for the United States and 171 for the Republic of Korea, because each document is there credited to a single country.

Productivity and citation impact diverged markedly (Table 2). The Netherlands produced 15 documents as corresponding-author country but attracted 59.7 citations per document. Conversely, India (7.36), China (7.51) and Japan (9.15) combined substantial output with comparatively low citation rates. Türkiye recorded the lowest mean among the twenty most productive countries, at 4.38 citations per document.

International collaboration was limited: only 11.78% of documents involved authors from more than one country. Among the ten most productive countries, multiple-country publication ratios were highest for France (21.4%), Germany (19.6%) and Italy (18.8%), and lowest for Japan (0.8%), India (2.7%), China (3.9%) and the Republic of Korea (4.7%). Ratios were higher still among several smaller contributors, including Belgium (60.0%), Brazil (36.4%), the Netherlands and Switzerland (both 33.3%) and Canada (27.8%), although each rests on between ten and eighteen documents (Table 3). Türkiye's ratio was 6.7%. The country collaboration network resolved into three communities (Figure 3): a cluster centred on the United States including the Republic of Korea, Japan, China, India, Türkiye and Brazil; a European cluster around Italy, France, Spain, Canada and Denmark; and a third grouping the United Kingdom, Germany, Austria, Switzerland, Belgium and Australia.

Yonsei University was the most productive institution with 50 documents and 23.6 citations per document, followed by the University of California System (39), the University of Texas System (37), Harvard University and the Mayo Clinic (35 each), and Ohio State University (34). Two of the ten most productive institutions were Korean (Table 4).

Author productivity was highly skewed and followed Lotka's law with a steeper exponent than the classical value of 2 ($\beta=3.471$; $R^2=0.984$): 7,519 authors (87.2%) contributed a single document, 778 (9.0%) two, and only 329 (3.8%) three or more (Figure 4). Chae Min Suk and Kim Young-Kug were the most prolific with twelve documents each, followed by Hong Sang Hyun, Hwang Jai-Hyun and Kim Na Young with eleven each. Productivity and influence were not equivalent: Kim Young-Kug, Hwang Jai-Hyun and Rha Koon Ho each achieved a within-corpus h-Index of 10, whereas authors with comparable document counts reached 6 or 7.

Journals and the Distribution of this Literature

Publications were dispersed across 422 journals. Bradford's law identified a core of 17 journals, with 68 in Zone 2 and 337 in Zone 3 ($R^2=0.9914$; Bradford multiplier $k=4.48$; Figure 5). Thus 4.0% of journals carried approximately one third of the literature.

The Journal of Robotic Surgery was the most productive source with 92 documents, followed by Surgical Endoscopy (49) and the Journal of Cardiothoracic and Vascular Anesthesia (41). Only three of the ten most productive journals were anaesthesiology journals (Table 5). Productivity and impact again diverged: the British Journal of Anaesthesia published 17 documents but attracted 59.9 citations per document, the highest of any core journal, while Anesthesia and Analgesia averaged 30.8 across 22 documents.

Table 3. Twenty most productive countries

Country	Documents (all affiliations)	Documents (corresponding author)	SCP	MCP	MCP ratio (%)	Total citations	Mean citations
USA	567	528	467	61	11.6	8,144	15.42
Republic of Korea	178	171	163	8	4.7	2,507	14.66
China	135	128	123	5	3.9	961	7.51
Japan	125	123	122	1	0.8	1,125	9.15
Italy	111	80	65	15	18.8	1,075	13.44
India	77	75	73	2	2.7	552	7.36
United Kingdom	73	51	44	7	13.7	781	15.31
Germany	62	46	37	9	19.6	886	19.26
Türkiye	52	45	42	3	6.7	197	4.38
France	60	42	33	9	21.4	663	15.79
Denmark	27	26	24	2	7.7	392	15.08
Canada	32	18	13	5	27.8	228	12.67
Taiwan	22	18	16	2	11.1	123	6.83
Australia	21	15	12	3	20.0	262	17.47
Netherlands	29	15	10	5	33.3	896	59.73
Spain	26	15	12	3	20.0	156	10.40
Switzerland	26	15	10	5	33.3	136	9.07
Brazil	19	11	7	4	36.4	93	8.45
Belgium	28	10	4	6	60.0	223	22.30
Singapore	11	10	9	1	10.0	202	20.20

Countries are ranked by the number of documents whose corresponding author was based in that country. Two counting bases are shown and they are not interchangeable. Documents (all affiliations) credits a document to every country represented among the affiliations of all its authors, so an internationally co-authored paper is counted once for each contributing country; these are the counts reported in the Results when total national contribution is described, and they sum to more than the 1,528 documents in the corpus. Documents (corresponding author) assigns each document to a single country and is the basis of Table 2, of the SCP and MCP counts and of the collaboration indices. Total and mean citations are given on the corresponding-author basis. Turkey and Türkiye were merged, as were England, Scotland, Wales and Northern Ireland. Mean citations for countries with few documents rest on small denominators and are correspondingly unstable. SCP: Single-country publications, MCP: Multiple-country publications

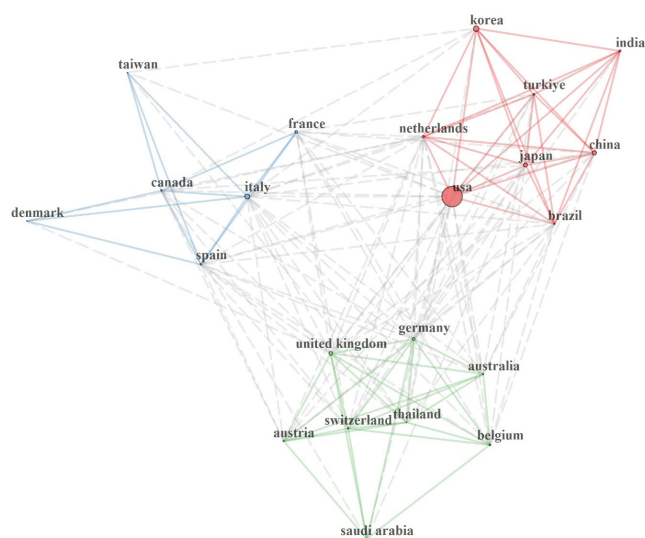


Figure 3. Country collaboration network. Node size is proportional to publication count; colour denotes cluster membership (Louvain algorithm). Top 22 countries shown

The distribution of this literature between anaesthesiology and surgical journals changed substantially over time (Figure 2). Anaesthesiology journals carried 48.5% of documents published between 2001 and 2008 and 51.8% between 2009 and 2012, but their share fell to 33.8% in 2013-2016, 26.6% in 2017-2020 and 21.9% in 2021-2025. Across the corpus the proportion was 26.8%. Absolute output in anaesthesiology journals rose over the same period from 16 to 187 documents, so the decline is proportional rather than absolute.

Table 4. Twenty most productive institutions

Institution	Documents	Total citations	Mean citations
Yonsei University	50	1,182	23.6
University of California System	39	849	21.8
University of Texas System	37	764	20.6
Harvard University	35	668	19.1
Mayo Clinic	35	337	9.6
Ohio State University	34	711	20.9
Cleveland Clinic Foundation	31	591	19.1
Seoul National University	31	338	10.9
Icahn School of Medicine at Mount Sinai	24	394	16.4
Pennsylvania Commonwealth System of Higher Education	23	394	17.1
State University System of Florida	23	296	12.9
Catholic University of Korea	20	125	6.2
University of Ulsan	20	345	17.2
Johns Hopkins University	19	679	35.7
University of Pittsburgh	19	320	16.8
University of Pennsylvania	17	166	9.8
Cornell University	16	130	8.1
Weill Cornell Medicine	15	119	7.9
Assistance Publique-Hôpitaux de Paris	14	183	13.1
University of California Los Angeles	14	307	21.9

Institutional names were harmonised with a purpose-built thesaurus before ranking, because Web of Science indexes parent systems and their constituent units as separate affiliations. Some residual overlap remains where a constituent unit could not be unambiguously assigned to a listed parent system

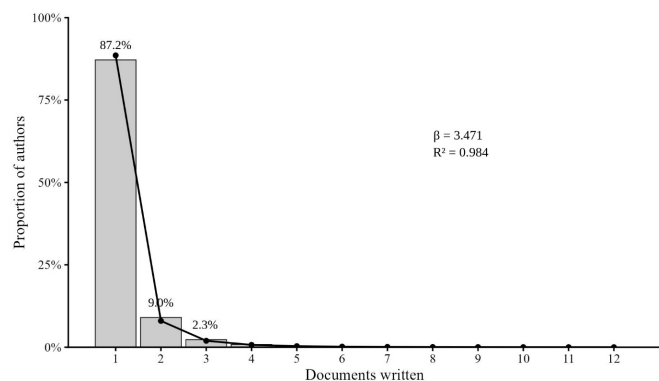


Figure 4. Author productivity distribution against Lotka's law

Bar labels give the proportion of authors at each exact level of productivity, so the label above the third bar refers to authors with exactly three documents. The 3.8% reported in the Results aggregates all authors with three or more documents and therefore corresponds to the third and all subsequent bars combined

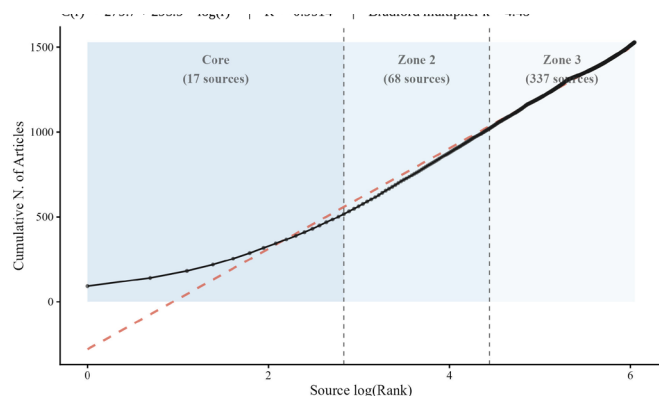


Figure 5. Bradford's law distribution of source journals

Most-cited Documents

The most-cited document was a randomised trial of multimodal prehabilitation published in JAMA Surgery in 2023 (415 citations), followed by a systematic review of enhanced recovery after urological surgery (242 citations) (Table 6). Three of the ten most-cited documents appeared in the British Journal of Anaesthesia and one in Anesthesia and Analgesia. The most-cited anaesthesia-specific investigations addressed the cardiovascular, cerebrovascular and respiratory consequences of steep Trendelenburg positioning combined with CO₂ pneumoperitoneum (189 citations),² intraocular pressure during steep Trendelenburg positioning (145 citations),³ and haemodynamic perturbation during robot-assisted radical prostatectomy in 45° Trendelenburg (119 citations).⁴

Thematic Structure

Keyword co-occurrence analysis resolved into three network communities (Figure 6): a positioning-physiology community (Trendelenburg position, pneumoperitoneum, intraocular pressure, positive end-expiratory pressure, propofol, general anaesthesia, robot-assisted radical prostatectomy); an analgesia community (postoperative pain, opioids, transversus abdominis plane block, regional anaesthesia, multimodal analgesia, thoracic surgery, transoral robotic surgery); and a recovery and outcomes community (ERAS, same-day discharge, length of stay, postoperative complications, radical cystectomy, partial nephrectomy).

Table 5. Ten most productive journals

Journal	Documents	Total citations	Mean citations	Zone	Category
Journal of Robotic Surgery	92	809	8.8	1	Surgical/other
Surgical Endoscopy and Other Interventional Techniques	49	725	14.8	1	Surgical/other
Journal of Cardiothoracic and Vascular Anesthesia	41	465	11.3	1	Anesthesiology
Journal of Clinical Medicine	37	351	9.5	1	Surgical/other
Journal of Endourology	35	580	16.6	1	Surgical/other
Asian Journal of Surgery	33	365	11.1	1	Surgical/other
BMC Anesthesiology	30	335	11.2	1	Anesthesiology
World Journal of Urology	26	313	12.0	1	Surgical/other
Journal of Minimally Invasive Gynecology	24	420	17.5	1	Surgical/other
Anesthesia and Analgesia	22	677	30.8	1	Anesthesiology

Zone denotes the Bradford's law zone; category denotes whether the journal is assigned to the Web of Science Anesthesiology subject category

Table 6. Ten most-cited documents

First author	Year	Journal	Citations	Citations per year	DOI
Molenaar CJL	2023	JAMA Surgery	415	103.8	10.1001/jamasurg.2023.0198
Azhar RA	2016	European Urology	242	22.0	10.1016/j.eururo.2016.02.051
Kalmar AF	2010	British Journal of Anaesthesia	189	11.1	10.1093/bja/aeq018
Finnerty DT	2020	British Journal of Anaesthesia	182	26.0	10.1016/j.bja.2020.06.020
Mitsala A	2021	Current Oncology	176	29.3	10.3390/curroncol28030149
Gandaglia G	2014	Journal of Clinical Oncology	168	12.9	10.1200/JCO.2013.53.5096
Awad H	2009	Anesthesia and Analgesia	145	8.1	10.1213/ane.0b013e3181a9098f
Ashrafian H	2017	British Journal of Anaesthesia	133	13.3	10.1093/bja/aex383
Kussman BD	2004	Pediatric Anesthesia	131	5.7	10.1046/j.1460-9592.2003.01192.x
Gainsburg DM	2012	Minerva Anestesiologica	128	8.5	PMID 22415437

Citations per year were calculated as total citations divided by the number of years since publication, inclusive of the publication year. The 2012 Minerva Anestesiologica article predates the assignment of digital object identifiers by that journal, so its PubMed identifier is given instead. DOI: Digital object identifier, PMID: PubMed identifier

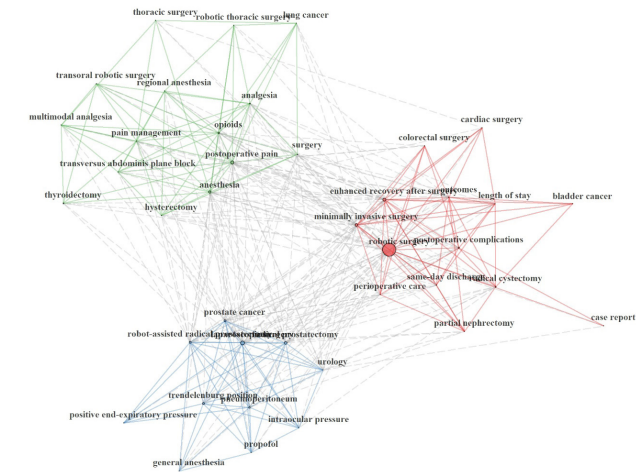


Figure 6. Author keyword co-occurrence network after thesaurus harmonisation. Node size is proportional to occurrence frequency; colour denotes cluster membership. Top 40 keywords shown

Thematic mapping identified five clusters (Table 7; Figure 7). Robotic surgery occupied the motor quadrant (966 keyword occurrences), radical prostatectomy sat on the motor-basic boundary (753) and carried the positioning-physiology terms, postoperative pain was a well-developed niche theme (490), ERAS was a basic theme (286), and thyroidectomy with transoral robotic surgery and sugammadex formed a small emerging cluster (69).

Table 7. Centrality and density values for the thematic clusters				
Cluster	Terms	Occurrences	Centrality	Density
Robotic surgery	22	966	0.300	8.66
Radical prostatectomy	23	753	0.193	8.05
Postoperative pain	23	490	0.122	10.36
Enhanced recovery after surgery	10	286	0.161	6.54
Thyroidectomy	3	69	0.038	5.53

Centrality measures the strength of a cluster's links to other clusters and density its internal cohesion, both computed by the Callon method on author keywords occurring at least six times. Clusters are ordered by keyword occurrence. Quadrant assignment in Figure 7 is based on median partitions of these values and should be read as indicative, since the radical prostatectomy and enhanced recovery after surgery clusters lie close to a partition line

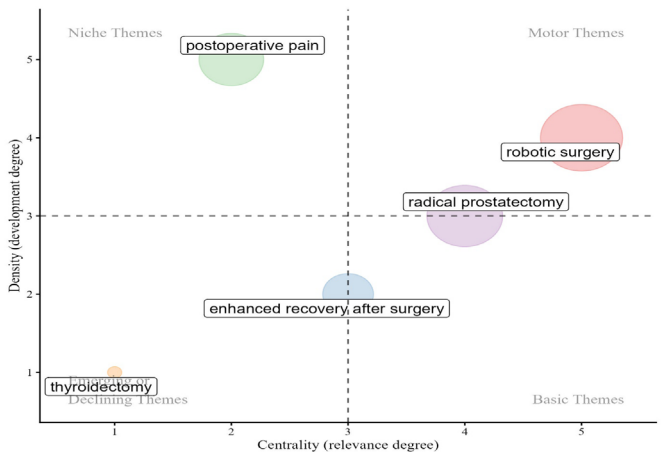


Figure 7. Thematic map of author keywords

Trend analysis showed an orderly succession (Figure 8). Cardiac surgery, intraocular pressure and Trendelenburg position peaked between 2015 and 2017; intracranial pressure, optic nerve sheath diameter, rhabdomyolysis, dexmedetomidine and transversus abdominis plane block between 2018 and 2019; pneumoperitoneum, radical cystectomy and laparoscopic surgery around 2020; and

postoperative pain, opioids and postoperative complications in 2022. The most recent terms were robotic thoracic surgery, ERAS, outcomes, colorectal surgery, lung cancer and Artificial Intelligence, all peaking in 2023 or 2024. Telesurgery, telemedicine and Artificial Intelligence were also present, but at low frequency: they were carried by 14, 11 and 10 documents respectively and all fell below the display threshold of the keyword co-occurrence network shown in Figure 6 (Table 8). They are therefore best regarded as emerging signals rather than as established themes.

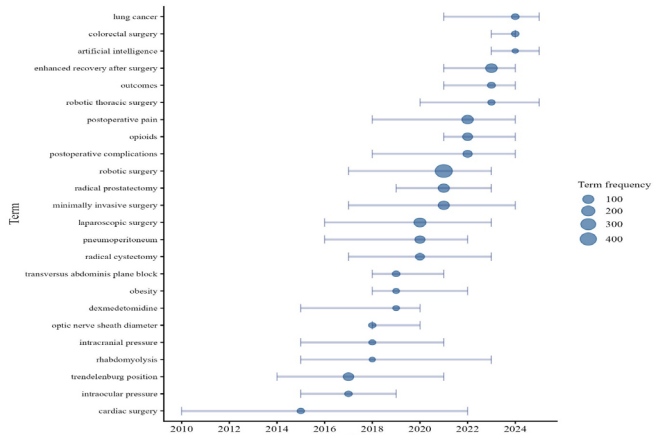


Figure 8. Trend topics by year. Circle position marks the median publication year of each term; horizontal bars span the first and third quartiles; circle size is proportional to term frequency

Table 8. Frequency and year range of terms denoting remote and computational approaches		
Term	Documents	Year range
Telesurgery	14	2007-2025
Telemedicine	11	2007-2025
Artificial Intelligence	10	2021-2025
5G	3	2021-2025
Remote surgery	2	2022-2025
Machine learning	1	2025

Terms were counted where they appeared in the title, author keywords or keywords plus of a document. Counts are not mutually exclusive. All fell below the display threshold of the keyword co-occurrence network shown in Figure 6

DISCUSSION

This analysis mapped 1,528 documents on perioperative anaesthetic management in robotic-assisted surgery indexed between 2001 and 2025. Three findings stand out.

Output grew at a compound annual rate of 14.6% between 2010 and 2025, and an exponential model accounted for 95% of the variance in the post-2009 trajectory. Yet the share of this literature appearing in anaesthesiology journals fell from 48.5% in 2001-2008 to 21.9% in 2021-2025, and only three of the ten most productive journals were anaesthesiology titles. Absolute output in anaesthesiology journals rose more than tenfold over the same interval, so this is dilution rather than retreat: expansion has been driven by publication in surgical and general medical venues. The pattern is intelligible. The early literature addressed questions only anaesthesiologists were positioned to ask, such as how steep head-down positioning combined with capnoperitoneum alters cardiovascular, cerebrovascular and respiratory homeostasis, and these studies appeared in anaesthesia journals.²⁻⁴ The recent literature is dominated by enhanced recovery pathways, opioid-sparing

protocols and same-day discharge, which are perioperative by definition but are increasingly designed, implemented and reported by surgical teams.^{6,7} One interpretation of this pattern, which these descriptive data can suggest but not demonstrate, is that anaesthesiologists increasingly contribute to an agenda they do not predominantly set and are less likely to encounter its findings in their own journals. Journal distribution indicates where this literature appears; it does not identify who designed, led or funded the underlying studies, so this reading should be treated as an implication of the findings rather than as a result established by them.

Productivity and citation impact were not equivalent. The United States produced 567 documents, more than three times the second-ranked country, but the highest citation rate belonged to the Netherlands (59.7 citations per document from 15 corresponding-author publications). Conversely, several high-output countries recorded low citation rates, including India (7.36), China (7.51) and Türkiye (4.38). The same divergence appeared at journal level, where the British Journal of Anaesthesia published only 17 documents but attracted 59.9 citations per document. These are descriptive associations and should not be read causally. Citation rates are shaped by journal selection, topic and language as much as by study quality, and means derived from small denominators are unstable.

Collaboration was limited and unevenly distributed. Only 11.78% of documents involved more than one country. The lowest multiple-country ratios belonged to the four most productive Asian contributors: Japan (0.8%), India (2.7%), China (3.9%) and the Republic of Korea (4.7%). Among the larger contributors, France (21.4%) and Germany (19.6%) were the most outward-facing; several smaller ones were more so still, including Belgium (60.0%), the Netherlands and Switzerland (both 33.3%) and Canada (27.8%). The Korean case is instructive: Yonsei University was the leading institution and Korean investigators occupied most leading author positions, reflecting a concentrated national programme built substantially around transoral and transaxillary robotic thyroidectomy, an approach with distinctive anaesthetic demands and one that formed its own thematic cluster. High productivity and low external collaboration can coexist, but the combination limits the generalisability of single-centre protocols. Türkiye ranked tenth in output but recorded the lowest citation rate among the twenty most productive countries and a multiple-country ratio of 6.7%. For Turkish anaesthesia departments, international co-authorship is the more actionable of these two gaps. The steep Lotka exponent ($\beta=3.471$), with 87.2% of authors contributing a single document, points in the same direction: the field has not yet consolidated a stable core of dedicated investigators.

The thematic sequence traces a coherent maturation. Attention moved from the immediate physiological consequences of the operative setting, such as intraocular and intracranial pressure, optic nerve sheath diameter and rhabdomyolysis, through regional analgesic technique, to recovery pathways and discharge outcomes. Postoperative pain emerged as a well-developed but peripheral niche theme, indicating an internally coherent literature not yet central to the field. The most recently rising terms are robotic thoracic surgery, Artificial Intelligence and telesurgery. The last two rest on a small evidence base, comprising 10 and 14 documents respectively (Table 8), and are more accurately described as

emerging topics, or as potential future research directions, than as established frontiers. The only Hot Paper in the corpus addressed ultra-long-distance robotic surgery. These topics raise anaesthetic questions that the current literature has barely addressed, including perioperative management when the operating surgeon is remote.

Practical Implications

Anaesthesiology departments involved in robotic programmes should recognise that much of the relevant evidence now appears outside anaesthesia journals and structure their literature surveillance accordingly. For countries combining substantial output with limited external collaboration, including Türkiye, multicentre and cross-national designs offer the clearest route to greater influence. The emerging topics identified here, and telesurgery in particular, are represented by few documents at present, but they invite anaesthetic engagement before practice patterns are established elsewhere.

Limitations

Four limitations apply. First, the analysis was confined to the Web of Science Core Collection. Work indexed only in Scopus, PubMed or regional databases was not captured, and approximately one fifth of records came from the Emerging Sources Citation Index, whose citation behaviour differs from that of the Science Citation Index Expanded. Second, restriction to English excludes non-English perioperative practice and may understate non-anglophone contributions. Third, citation counts favour older publications, so recent work is systematically under-represented in impact measures. Fourth, the corpus was defined primarily by the search strategy. Although both authors reviewed all records flagged by an automated consistency check and excluded none, the boundary between anaesthetic and surgical content is not always sharp and a different eligibility threshold would yield a somewhat different corpus.

CONCLUSION

Research on perioperative anaesthetic management in robotic-assisted surgery has grown rapidly and continuously since 2009, with more than half of the literature published in the last five years. The United States leads output, followed by the Republic of Korea, and Yonsei University is the most productive institution. The literature is dispersed across 422 journals, with a core of 17 accounting for approximately one third of output. Two findings deserve particular attention: citation impact is concentrated in countries and journals of modest output rather than in the largest producers, and the proportion of this literature published in anaesthesiology journals has fallen by more than half since the field's early period. As robotic surgery continues to expand, and as telesurgery and Artificial Intelligence appear as potential future research directions, these patterns suggest that deliberate engagement by anaesthesiologists, through international collaboration and through publication in their own specialty venues, may help to keep the perioperative dimension of this field shaped by anaesthetic expertise. This is an implication of the publication patterns described here rather than a conclusion demonstrated by them.

ETHICAL DECLARATIONS

Ethics Committee Approval

As the study is based solely on previously published and publicly available bibliographic records, ethics committee approval was not required.

Informed Consent

Since this research is a bibliometric study, it did not require informed consent.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Author Contributions

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