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# Enhanced Recovery After Surgery for Vascular Surgery

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## Abstract

Enhanced Recovery After Surgery (ERAS) protocols are interventions that aim to improve recovery after surgical procedures. The objective of the topic brief is to identify and categorize the existing effectiveness and comparative effectiveness ERAS literature for vascular surgery to determine whether there is sufficient literature to warrant a systematic review on the topic.

In a scoping search in July 2019, we identified 947 completed or ongoing empirical studies addressing aspects of ERAS that varied in their applicability to vascular surgery. Only 115 studies focused exclusively on vascular surgery patients and evaluated an aspect of ERAS.

Although the evidence base on vascular surgery is still growing, a systematic review of the available literature appears to be feasible. For individual aspects of ERAS protocols, evidence from vascular surgery may need to be combined with mixed samples and ERAS protocol research applicable to vascular surgery. The results of the topic brief are only an estimate of the available literature.

## Acknowledgments

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## Introduction and Background

Enhanced Recovery After Surgery (ERAS) protocols are interventions designed to support patients recovering from surgery, and they may span the entire care continuum—from preadmission to preoperative to intraoperative to postoperative care.<sup>1</sup> ERAS protocols have shown to decrease both length of stay and the number of surgical complications in uses such as colorectal surgery, gynecologic/oncology surgery, and liver surgery. In fact, the ERAS Society has developed a number of clinical guidelines, sometimes in collaboration with institutions such as The European Society for Clinical Nutrition and Metabolism, based on the results of systematic reviews of ERAS in different settings.<sup>2</sup> However, there has not been a systematic effort to review literature related to ERAS in the context of vascular surgery. Vascular surgeries range from major open operations, such as open aortic aneurysm repair or lower extremity bypass, to less invasive endovascular procedures.<sup>3</sup>

The Society for Vascular Surgery has a number of clinical guidelines and implementation resources to support providers and hospitals on topics such as the management of venous leg ulcers, early thrombus removal strategies for acute deep vein thrombosis, and the comparative effectiveness of treatments for aortic transection.<sup>4</sup> Given the identified benefits of ERAS in other surgical approaches, the Society for Vascular Surgery seeks to better understand the breadth, depth, and content of literature that might be available to inform clinical guidelines on the use of ERAS in vascular surgeries. This topic brief was commissioned by the Patient-Centered Outcomes Research Institute (PCORI) to determine whether there is sufficient research literature to support a systematic review on ERAS protocols relevant to vascular surgery.

## Objective

The objective of this topic brief is to identify and categorize the existing effectiveness and comparative effectiveness literature on ERAS protocols relevant to vascular surgery.

## Key questions

The topic brief will answer 3 key questions:

1. What are the size and composition (eg, study designs) of the evidence examining the effectiveness and comparative effectiveness of ERAS interventions, either as individual core elements of ERAS programs or in combination as ERAS multimodal care pathways, in the specific setting of vascular surgery?
  - Preadmission interventions and care pathways, such as patient education and screening on tobacco abuse; and medical screening and optimization, including cognitive impairment screening and antiplatelet and anticoagulation planning
  - Preoperative interventions, such as limited fasting and carbohydrate loading (especially for patients with diabetes), preemptive analgesia, and antiemetic prophylaxis
  - Intraoperative interventions, such as specific surgical techniques, anesthetic plans, and fluid management strategies

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- Postoperative interventions, such as patient warming, fluid management strategies, multimodal analgesia, opioid minimization strategies, drain and line management, early mobilization strategies, diet and bowel regimens, and discharge planning
2. What are the number and composition of available trials studying ERAS programs (as multimodal care pathways) across all types of surgical settings?
  3. What ERAS interventions have interventional or observational research in the published literature that are specific either to vascular surgical procedures (ie, individual ERAS core elements or the broader ERAS care pathway) or to the broader surgical literature (ie, multimodal care programs only)?

## Methods

The topic brief, which was informed by the literature and content experts, followed the protocol outlined below.

### Stakeholder call

A stakeholder call with the topic nominator—ie, representatives from the Society for Vascular Surgery—and the project funder (PCORI) provided input to ensure that the review is appropriately targeted to answer the key questions.

### Literature searches

The search strategy was developed by the study co–principal investigators (Drs. Hempel and Rollison) and informed by input from the Society for Vascular Surgery and PCORI as well as existing reviews on the topic. A reference librarian, specializing in literature reviews, executed and documented the search in July 2019. The topic brief assesses only the feasibility of a systematic review and the searches were exploratory in nature. The searches did not include every source that would be searched in a comprehensive systematic review (eg, additional databases such as EMBASE). However, the searched sources are sufficiently informative to answer the 3 key questions, and while not designed to be comprehensive, provide insight into the full evidence base.

### Sources

For published literature, we searched the following research databases:

- PubMed (biomedical literature)
- CINAHL (nursing research)

The search strategy is documented in the appendix. The databases were most relevant to the topic and well suited to allow an estimate of the literature. We also conducted a PubMed search for systematic reviews to reference-mine reviews on ERAS in vascular surgery. For unpublished and ongoing research, we searched a research registry:

- Clinicaltrials.gov

This database is well maintained, automatically indexes research from other databases by screening for the unique trial ID, and includes trials and large observational studies. We

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restricted the search to trials that have stopped recruiting (ie, those that are close to completion and likely relevant for a systematic review in the near future).

### Inclusion screening

An experienced literature reviewer screened the results of the literature searches for relevance and documented them using citation management software. The inclusion screening criteria were as follows:

- *Population*: Patients of any age undergoing surgical procedures
- *Intervention*: Interventions that aim to enhance recovery after surgery; this includes preadmission ERAS interventions and care pathways (eg, patient education, screening on tobacco abuse, medical screening and optimization, cognitive impairment screening, antiplatelet and anticoagulation planning), preoperative ERAS interventions (eg, limited fasting, carbohydrate loading, preemptive analgesia, antiemetic prophylaxis), intraoperative ERAS interventions (eg, specific surgical techniques, anesthetic plans, fluid management strategies), and postoperative ERAS interventions (eg, patient warming, fluid management strategies, multimodal analgesia, opioid minimization strategies, drain and line management, early mobilization strategies, diet and bowel regimens, and discharge planning). We included comparisons of vascular and endovascular procedures; we accepted open thoracic, open abdominal, and lower extremity bypass as vascular surgery, but we excluded studies on carotid endarterectomy and nonsurgical vascular procedures (eg, angioplasty). We also excluded all interventions not directly aimed at patients' recovery, studies assessing the effects of surgical interventions compared with other alternatives (eg, gastric bypass vs lifestyle intervention), interventions not associated with recovery from surgery, and studies comparing 2 surgical interventions without reference to recovery.
- *Comparator*: We placed no restrictions on the type of comparator, but either a historic (eg, pre-ERAS intervention) or concurrent (eg, control group in a clinical trial) comparator had to be reported. We excluded analytic studies aiming to identify predictors of early recovery.
- *Outcomes*: Patient health outcomes relevant to recovery, such as mortality, postoperative complications, functional status, postoperative pain control, postoperative time to regular diet, postoperative time to ambulation, hospital length of stay, discharge disposition, or readmissions. We excluded studies exclusively reporting preoperative or perioperative outcomes, acceptability, feasibility, procedure volume, and physiological or invitro indicators.
- *Study design*: Studies evaluating the effectiveness of an intervention (randomized controlled trials [RCTs]; clinical trials with nonrandom intervention assignment by investigator; cohort studies comparing 2 observational cohorts undergoing different interventions or matched control groups; case series, time series, or pre-post studies). We excluded post-only studies because the effects of ERAS are indistinguishable from the completed surgery. Systematic reviews on vascular surgery were retained for reference mining.
- *Timing*: Interventions from preoperative clinic visit/decision for surgery through 90 days postoperative

We placed no restrictions on the timing of the follow-up or the setting. Because multiple publications are very common, the literature reviewer paid particular attention to linked



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publications so that multiple publications from one study were not counted multiple times but were considered as contributing information about one research study. We excluded studies without abstracts and those published in abbreviated form (eg, conference abstract), as these did not provide sufficient information for this topic brief.

### Study categorization

Once screened for relevance, we categorized the literature using a broad categorization system to support answers to the 3 key questions:

- Study design
  - RCT (random allocation to intervention group)
  - Clinical trial (intervention assignment by investigator but not randomized)
  - Cohort study (comparing 2 or more cohorts exposed to different interventions)
  - Pre–post study, case series, time series (historic control)
- Study population
  - Vascular (vascular surgery)
  - Mixed (mixed surgery; may include vascular surgery)
  - Applicable (not vascular surgery but relevant and compatible; eg, abdominal surgery, extremity surgeries)\*
  - Tangential (not vascular surgery and findings likely not applicable)
- Intervention type
  - Preadmission (started before admission to hospital/clinic)
  - Preoperative (started before surgery)
  - Intraoperative (during surgery, including surgical techniques)
  - Postoperative (started after surgery)
  - Other/unclear interventions

We determined the relevance of the study population based on the relevance to vascular surgery. We differentiated vascular surgery studies and studies that explicitly include vascular surgery (eg, mixed samples) as well as studies that address interventions associated with those other than vascular surgery interventions but that are generally applicable to surgical settings, such as patient information. Finally, we noted studies that describe ERAS interventions that were not relevant to vascular surgery, that are likely not compatible with vascular procedures, and whose results will not generalize to vascular surgery applications.

We categorized ERAS interventions that were applied before admission to the hospital or facility and interventions that were started before the surgical procedure (ie, preoperatively). Preoperative interventions included those that were started before the surgical procedure but whose interventions may have continued during and after the surgery (eg, prophylactic antibiotics). Intraoperative interventions included all interventions that took place concurrently to the surgical procedure or addressed the surgical procedures itself (eg, the study tested 2 alternative surgery options). Postoperative interventions included all interventions that were started after the surgical procedure was complete.

We based the outlined categorizations on the title and abstract of the publication in most studies, to allow us to process a large amount of data in a short amount of time. However, when an important determination was not possible, we attempted to obtain and review the full text of the publication if it was either open access or available through the RAND Knowledge Service

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\* The team's content expert reviewed individual cases to assess relevance and compatibility.



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Department (the department subscribes to 30 000 journals). Not all studies were available as full text.

## Results

The searches identified 3478 citations. These included 123 systematic reviews potentially relevant to ERAS. However, only 11 systematic reviews addressed vascular procedures or targeted general surgery topics that may have included vascular surgery studies, and we found none that specifically addressed ERAS in vascular surgery.

We identified 947 completed and ongoing studies published in 965 publications relevant to the topic brief questions.<sup>5-969</sup>

**Key Question 1: What are the size and composition of the evidence examining the effectiveness and comparative effectiveness of ERAS interventions, either as individual core elements of ERAS programs or in combination as ERAS multimodal care pathways, in the specific setting of vascular surgery?**

We identified 115 empirical studies addressing ERAS approaches in vascular surgery.<sup>29, 40, 65, 75, 84, 89, 99, 110, 118, 130, 145, 146, 156, 177, 188, 192, 198, 240, 254, 255, 269, 285, 301, 312, 316, 321, 330, 336, 350, 354, 357, 393, 395, 409, 411, 423, 433, 434, 438, 441, 457, 467, 476, 479, 481, 499, 500, 502, 504, 506, 513, 527, 544, 545, 551, 559, 574, 576, 578, 591, 605, 609, 620, 633, 639, 644, 648, 661, 666, 671-673, 685, 697, 702, 709, 711, 714, 717, 718, 720, 754, 808, 813, 821, 825, 827, 858, 867, 888, 892, 896, 901, 910, 911, 913, 914, 919, 924-926, 928, 936, 938-941, 948, 952, 964-969</sup> These included 2 ongoing trials for which the results are not yet published, but the trials have stopped recruiting participants and results may be available in the near future.<sup>948, 952</sup>

A classification of studies by design and intervention type is documented in Table 1.

**Table 1. ERAS in Vascular Surgery**

Intervention	Vascular Surgery			
	RCTs	CT	Cohort	Pre-Post
Preadmission n = 0	n = 0	n = 0	n = 0	n = 0
Preoperative n = 28 <sup>40, 110, 145, 146, 177, 354, 476, 479, 527, 545, 620, 633, 639, 644, 648, 661, 672, 697, 711, 714, 827, 888, 919, 928, 939, 940, 948, 952</sup>	n = 27 <sup>40, 110, 145, 146, 177, 354, 476, 479, 527, 545, 620, 633, 639, 644, 648, 661, 672, 697, 711, 714, 827, 919, 928, 939, 940, 948, 952</sup>	n = 1 <sup>888</sup>	n = 0	n = 0
Intraoperative n = 51 <sup>89, 118, 198, 240, 254, 312, 330, 393, 395, 409, 411, 423, 433, 434, 467, 481, 499, 500, 502, 504, 544, 559, 574, 578, 591, 605, 609, 666, 671, 673, 709, 717, 718, 720, 754, 808, 813, 821, 858, 867, 892, 901, 913, 914, 924, 925, 936, 941, 964, 966, 969</sup>	n = 38 <sup>118, 198, 240, 393, 395, 411, 423, 433, 434, 481, 499, 500, 504, 544, 559, 574, 605, 609, 671, 673, 709, 717, 718, 720, 808, 813, 821, 858, 867, 892, 901, 913, 914, 924, 925, 936, 941, 964</sup>	n = 5 <sup>254, 409, 502, 591, 666</sup>	n = 7 <sup>89, 312, 330, 467, 578, 754, 966</sup>	n = 1 <sup>969</sup>
Postoperative n = 25 <sup>29, 65, 75, 84, 99, 130, 188, 255, 269, 285, 321, 336, 350, 357, 438, 506, 513, 576, 702, 825, 896, 910, 911, 926, 938</sup>	n = 17 <sup>29, 75, 84, 188, 255, 269, 350, 438, 506, 513, 576, 702, 825, 910, 911, 926, 938</sup>	n = 4 <sup>99, 321, 357, 896</sup>	n = 2 <sup>285, 336</sup>	n = 2 <sup>65, 130</sup>
Bundle, mixed, and/or phase not reported n = 11 <sup>156, 192, 301, 316, 441, 457, 551, 685, 965, 967, 968</sup>	n = 3 <sup>441, 685, 965</sup>	n = 0	n = 1 <sup>316</sup>	n = 7 <sup>156, 192, 301, 457, 551, 967, 968</sup>
Total	n = 85	n = 10	n = 10	n = 10

*Abbreviations: CT, clinical trial, intervention allocation by investigator but not randomized; ERAS, enhanced recovery after surgery; cohort study comparing 2 or more groups exposed to different interventions; n, number of studies; pre-post study comparing results before and after the implementation of ERAS; RCT, randomized controlled trial.*

The most common study design to evaluate ERAS protocols was an RCT. The comparators in the studies varied but were typically usual care without ERAS protocols.

The studies addressed preoperative, intraoperative, and postoperative ERAS interventions. We did not identify studies in which the evaluated intervention took place prior to admitting the patients. A few studies evaluated intervention bundles that spanned phases or did not report when the intervention was applied in the care continuum (ie, preoperative, perioperative, or postoperative). Bundles included, for example, a multimodal clinical program that combined a less invasive operative approach, epidural anesthesia, early feeding, and early mobilization in a sample of patients undergoing open abdominal aortic surgery.<sup>551</sup>

The preoperative studies that started an ERAS intervention before the surgical procedure evaluated many different approaches, including comprehensive geriatric assessment,<sup>110</sup>

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preoperative optimization of cardiac function,<sup>697</sup> or acid-reducing prophylaxis.<sup>633</sup> However, the most common intervention was antibiotics prophylaxis.<sup>620, 639, 672, 711, 714, 928</sup>

The intraoperative interventions evaluated a variety of different interventions. These included comparisons of the impact of different vascular surgical techniques (eg, vertical or transverse incisions for access to the femoral artery,<sup>411</sup> hand-assisted laparoscopy and conventional median laparoscopy<sup>504</sup>) on outcomes such as wound complications (eg, infections, lymphatic leaks), length of hospital stay, and early recovery data (ie, hours to resume fluid and solid diet).<sup>89, 118, 240, 409, 411, 502, 504, 578, 754</sup> Furthermore, several studies evaluated different anesthesia regimens and their effects on patient recovery after surgery.<sup>312, 559, 709, 813, 821, 892, 901, 914, 924, 936</sup>

The postoperative studies that implemented an ERAS element following the surgical procedure evaluated many unique interventions, such as a collaborative care model,<sup>130</sup> nutrition-related protocols,<sup>336, 438, 702</sup> or infection control.<sup>99, 269, 926</sup> Many studies addressed different wound dressing approaches<sup>29, 65, 75, 84, 99, 255, 269, 350</sup> and pain control approaches.<sup>285, 506, 825, 896, 910</sup>

## Key Question 2: What are the number and composition of available trials studying ERAS programs (as multimodal care pathways) across all types of surgical settings?

We identified a substantial number of ERAS interventions that are being evaluated in ongoing trials or completed studies. Table 2 shows the number of studies broken down by study design.

**Table 2. ERAS Across Surgical Settings**

ERAS Studies Publication Status	ERAS Study Designs
Ongoing studies (n = 20) <sup>944-963</sup>	RCT (n = 20) <sup>944-963</sup>
Completed or partially published studies (n = 927) <sup>5-140, 142-166, 168-186, 188-235, 237-258, 259-295, 297-351, 353-355, 357-379, 381-454, 456-513, 514-519, 521-523, 525-615, 617-625, 627-685, 688-755, 757-770, 771-785, 787-853, 855-943, 964-969</sup>	<p>RCT (n = 719)<sup>5, 6, 9-11, 13, 16, 18-22, 25-29, 31-33, 35, 37, 40-42, 44-46, 48-50, 52, 54-58, 62, 64, 66-70, 72-78, 80-87, 90, 92-95, 97, 102-104, 107, 109-113, 115-119, 122, 123, 125-127, 129, 132, 133, 137-140, 143-146, 148-155, 157, 158, 160-165, 169-174, 176, 177, 179-182, 186, 188, 189, 191, 193-203, 205-209, 212-214, 216, 218, 219, 222, 224, 226-230, 232-234, 238-241, 243-246, 248-253, 255-258, 260-262, 265, 267-273, 276-283, 287-291, 293-295, 299, 300, 302-304, 307-309, 311, 314, 315, 317, 320, 322, 323, 326-328, 331-335, 337, 339, 341, 343, 344, 346-351, 354, 355, 359, 363-365, 368-371, 373-379, 381-386, 389-396, 398, 400-405, 407, 408, 411-413, 415, 416, 418, 421-441, 444-448, 450, 452, 454, 456, 459, 462-464, 468, 469, 471-489, 491-497, 499-501, 503-507, 509-516, 518, 519, 521-523, 526-537, 539-542, 544-550, 552, 554-576, 579-581, 583-590, 592, 593, 596-598, 600, 601, 603-609, 611, 612, 615, 617, 619-622, 624, 627-631, 633, 634, 636-646, 648, 649, 651-654, 656, 658, 659, 661-664, 667, 668, 670-676, 678-685, 688-694, 696, 697, 699, 700, 702-711, 713-726, 728-736, 738-741, 743-751, 753, 755, 758-765, 767-771, 773-775, 777, 779-783, 785, 787-797, 800-810, 812-823, 825-828, 830, 831, 833-843, 844-853, 855-860, 862, 864-871, 873-887, 889-895, 897-905, 907-921, 923-926, 928, 930-932, 934-942, 964, 965</sup></p> <p>CT (n = 85)<sup>8, 30, 36, 38, 39, 60, 63, 71, 88, 99, 100, 105, 124, 131, 134, 142, 183, 210, 211, 215, 220, 237, 254, 321, 342, 353, 357, 358, 366, 367, 372, 387, 388, 406, 409, 410, 419, 420, 442, 443, 449, 458, 465, 466, 490, 498, 502, 508, 517, 525, 538, 543, 577, 582, 591, 594, 602, 614, 623, 625, 647, 657, 666, 698, 701, 712, 727, 737, 752, 766, 784, 798, 799, 811, 824, 861, 863, 872, 888, 896, 906, 922, 927, 929, 933</sup></p> <p>Cohort (n = 83)<sup>7, 12, 15, 17, 23, 24, 43, 47, 61, 79, 89, 91, 96, 101, 108, 114, 121, 128, 147, 159, 166, 175, 185, 217, 221, 225, 247, 263, 264, 274, 284-286, 292, 298, 305, 310, 312, 313, 316, 318, 319, 329, 330, 336, 338, 340, 345, 360-362, 397, 399, 414, 417, 451, 460, 461, 467, 470, 553, 578, 595, 599, 610, 618, 632, 635, 655, 660, 665, 669, 677, 695, 742, 754, 772, 776, 778, 829, 832, 943, 966</sup></p> <p>Pre-post (n = 40)<sup>14, 34, 51, 53, 59, 65, 98, 106, 120, 130, 135, 136, 156, 168, 178, 184, 190, 192, 204, 223, 231, 235, 242, 259, 266, 275, 297, 301, 306, 324, 325, 453, 457, 551, 613, 650, 757, 967-969</sup></p>

Abbreviations: CT, clinical trial; ERAS, enhanced recovery after surgery; n, number of studies; RCT, randomized controlled trial.

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The table shows the available evidence for aspects of ERAS across the range of surgical settings. Several existing studies used an RCT design randomizing patients to an ERAS or a non-ERAS intervention arm. All studies categorized as ERAS were ongoing RCTs. We also identified a number of clinical trials for which the study summary indicated that the treatment allocation was under the control of the investigator, but patients were not randomized. The studies classified as cohort studies included all studies that followed patients exposed to different interventions. We identified only a small number of pre–post studies that compared the impact of an ERAS intervention with a pre-ERAS period in which the protocol was not in place in the health care delivery organizations. All the included pre–post studies have a historic comparator and secular effects (eg, other changes in treatment advances or patient composition over time) cannot be distinguished from the effects of the ERAS protocol.

The reference section documents the large variety of available evaluations that are completed and for which (at least some) results are in the public domain. In addition, we restricted the search for ongoing studies to those that have stopped recruiting participants and are likely to be available to be included in a systematic review in the near future.

**Key Question 3: What ERAS interventions have interventional or observational research in the published literature that are either specific to vascular surgical procedures (ie, individual ERAS core elements or the broader ERAS care pathway), or to the broader surgical literature (ie, multimodal care programs only)?**

We stratified the identified literature by broad study design category across all identified studies. In addition, we rated every study intervention according to its applicability to vascular surgery. Table 3 shows the breakdown of available evidence by study design and applicability to vascular surgery.

**Table 3. ERAS Studies' Design and Applicability to Vascular Surgery**

ERAS Studies' Designs	ERAS Studies' Applicability to Vascular Surgery
<p>Interventional research (n = 823)</p> <p>RCTs, CTs</p> <p>Observational research (n = 123)</p> <p>Cohort, Pre-post studies</p>	<p>Vascular surgery (n = 115)<sup>29, 40, 65, 75, 84, 89, 99, 110, 118, 130, 145, 146, 156, 177, 188, 192, 198, 240, 254, 255, 269, 285, 301, 312, 316, 321, 330, 336, 350, 354, 357, 393, 395, 409, 411, 423, 433, 434, 438, 441, 457, 467, 476, 479, 481, 499, 500, 502, 504, 506, 513, 527, 544, 545, 551, 559, 574, 576, 578, 591, 605, 609, 620, 633, 639, 644, 648, 661, 666, 671-673, 685, 697, 702, 709, 711, 714, 717, 718, 720, 754, 808, 813, 821, 825, 827, 858, 867, 888, 892, 896, 901, 910, 911, 913, 914, 919, 924-926, 928, 936, 938-941, 948, 952, 964-969</sup></p> <p>Mixed (n = 18)<sup>77, 265, 388, 491, 523, 597, 612, 705, 707, 708, 713, 884, 903, 915, 920, 930, 933, 942</sup></p> <p>Applicable (n = 462)<sup>5, 8-11, 13-15, 17-21, 23-27, 30-34, 36, 41-43, 45, 46, 48-51, 53, 55, 56, 58-64, 66, 67, 69, 70, 72-74, 79-81, 83, 85, 86, 88, 91-93, 96-98, 100-107, 109, 111, 112, 114, 116, 119-123, 125, 128, 129, 131, 133, 135, 136, 139, 140, 143, 149-152, 155, 158, 161, 164, 166, 168-172, 174-176, 178, 180, 182-186, 190, 191, 193, 195, 199, 201, 203, 204, 206-209, 211, 219, 221, 223, 225, 227, 231-233, 235, 237, 239, 241-243, 246-249, 252, 253, 256, 258, 260, 262, 264, 266, 270, 272, 273, 276-278, 282, 284, 288, 291-295, 297-300, 302-304, 306, 309-311, 313-315, 320, 324, 325, 328, 329, 332, 335, 337, 338, 340, 343, 346-348, 351, 353, 359, 361, 362, 364, 365, 373, 374, 376, 377, 381-383, 386, 397, 401, 404, 407, 408, 410, 412-414, 416, 417, 421, 424-428, 442, 444-447, 449-453, 456, 458, 465, 466, 468, 469, 473, 475, 477, 480, 483, 485, 488, 489, 493, 495, 505, 507, 510, 511, 515, 516, 518, 519, 521, 522, 525, 528, 530, 534, 539, 540, 542, 543, 550, 555, 557, 560, 562, 564, 565, 567, 568, 571-573, 579, 583, 584, 587, 588, 592, 595, 596, 599, 600, 602, 603, 608, 611, 625, 627-630, 638, 642, 643, 646, 647, 650, 655, 658-660, 662, 663, 667, 668, 675, 678, 681-683, 690, 692, 693, 695, 700, 703, 704, 710, 715, 716, 723, 725, 726, 728, 731, 735, 736, 739, 740, 742, 744-749, 752, 753, 755, 757, 759, 761, 766, 777-785, 787-793, 797, 799, 800, 803, 805, 806, 809, 811, 812, 814, 817, 819, 822, 824, 826, 828, 830-835, 837, 839-850, 852, 853, 855, 859, 864-866, 868, 869, 876-879, 881-883, 885-887, 889-891, 894, 895, 897-900, 904-907, 909, 912, 916-918, 921-923, 929, 931, 937, 943-946, 949, 950, 953, 955-957, 961-963</sup></p> <p>Unclear (n = 2)<sup>137, 722</sup></p> <p>Tangential (n = 350)<sup>6, 7, 12, 16, 22, 28, 35, 37-39, 44, 47, 52, 54, 57, 68, 71, 76, 78, 82, 87, 90, 94, 95, 108, 113, 115, 117, 124, 126, 127, 132, 134, 138, 142, 144, 147, 148, 153, 154, 157, 159, 160, 162, 163, 165, 173, 179, 181, 189, 194, 196, 197, 200, 202, 205, 210, 212-218, 220, 222, 224, 226, 228-230, 234, 238, 244, 245, 250, 251, 257, 259, 261, 263, 267, 268, 271, 274, 275, 279-281, 283, 286, 287, 289, 290, 305, 307, 308, 317-319, 322, 323, 326, 327, 331, 333, 334, 339, 341, 342, 344, 345, 349, 355, 358, 360, 363, 366-372, 375, 378, 379, 384, 385, 387, 389-392, 394, 396, 398-400, 402, 403, 405, 406, 415, 418-420, 422, 429-432, 435-437, 439, 440, 443, 448, 454, 459-464, 470-472, 474, 478, 482, 484, 486, 487, 490, 492, 494, 496-498, 501, 503, 508, 509, 512, 514, 517, 526, 529, 531-533, 535-538, 541, 546-549, 552-554, 556, 558, 561, 563, 566, 569, 570, 575, 577, 580-582, 585, 586, 589, 590, 593, 594, 598, 601, 604, 606, 607, 610, 613-615, 617-619, 621-624, 631, 632, 634-637, 640, 641, 645, 649, 651-654, 656, 657, 664, 665, 669, 670, 674, 676, 677, 679, 680, 684, 688, 689, 691, 694, 696, 698, 699, 701, 706, 712, 719, 721, 724, 727, 729, 730, 732-734, 737, 738, 741, 743, 750, 751, 758, 760, 762-765, 767-776, 794-796, 798, 801, 802, 804, 807, 810, 815, 816, 818, 820, 823, 829, 836, 838, 851, 856, 857, 860-863, 870-875, 880, 893, 902, 908, 927, 932, 934, 935, 947, 951, 954, 958-960</sup></p>

Abbreviations: CT, clinical trial; ERAS, enhanced recovery after surgery; n, number of studies; RCT, randomized controlled trial.

The identified research evidence in vascular surgery is documented under key question 1. In addition to the research in vascular surgery, we also identified 18 studies that evaluated interventions in mixed patient samples (ie, studies included at least some patients undergoing vascular surgery); hence, the interventions are applicable to patients undergoing vascular surgery. The studies addressed a range of interventions, such as preoperative counseling,<sup>388</sup> prophylactic antibiotics,<sup>707, 708, 713, 930, 933</sup> reduction of postoperative shivering,<sup>920</sup> fluid loading programs,<sup>523</sup> enteral feeding schedules,<sup>491</sup> or different discharge planning.<sup>942</sup> However, the results of the studies should be regarded with caution since they were only partially derived from patients undergoing vascular surgery.

In addition, we identified a large number of studies that were not based on vascular surgery but appear to be applicable to patients undergoing these surgeries. The 462 studies are documented in the reference section. Some interventions do not explicitly state that the aim of the intervention was to improve patients' recovery from surgery, but the studies address relevant patient-centered indicators of recovery from surgery. Table 4 summarizes the studies from mixed patient samples as well as those applicable to patients undergoing vascular surgeries. Given the importance of RCTs for strong evidence statements, we stratified RCTs and other study designs.

**Table 4. Evidence Summary of Potentially Additionally Relevant Studies (Mixed and Applicable Samples)**

Intervention Phase	Mixed (n = 18)		Applicable (n = 462)	
	RCTs	Other Studies	RCTs	Other Studies
Preadmission	n = 0	n = 0	n = 1 <sup>260</sup>	n = 0
Preoperative	n = 4 <sup>7, 13, 884, 915, 930</sup>	n = 2 <sup>388, 933</sup>	n = 31 <sup>5, 10, 11, 69, 109, 209, 262, 273, 295, 376, 381, 404, 450, 519, 611, 642, 682, 683, 703, 710, 715, 723, 744, 780, 790, 791, 834, 843, 850, 886, 950</sup>	n = 3 <sup>742, 778, 943</sup>
Intraoperative	n = 3 <sup>597, 612, 708</sup>	n = 0	n = 136 <sup>18-20, 26, 42, 46, 70, 73, 81, 85, 92, 103, 125, 140, 143, 152, 201, 203, 206, 243, 288, 299, 304, 347, 351, 401, 407, 424, 427, 428, 445, 446, 456, 473, 480, 483, 489, 493, 507, 515, 516, 542, 550, 555, 557, 560, 564, 565, 568, 571, 572, 583, 584, 587, 588, 592, 596, 629, 630, 638, 643, 646, 658, 659, 662, 667, 668, 675, 678, 681, 692, 693, 700, 704, 716, 731, 735, 740, 748, 759, 761, 777, 781, 782, 789, 792, 812, 814, 817, 819, 822, 828, 830, 831, 833, 844-846, 848, 849, 852, 855, 859, 864, 865, 868, 869, 876-879, 882, 883, 885, 887, 889, 890, 894, 897-900, 905, 907, 912, 916, 917, 923, 931, 937, 953, 955-957, 961, 962</sup>	n = 10 <sup>30, 88, 221, 292, 595, 647, 824, 906, 922, 929</sup>



Table 4. (continued)

Intervention Phase	Mixed (n = 18)		Applicable (n = 462)	
	RCTs	Other Studies	RCTs	Other Studies
Postoperative	n = 8 <sup>77, 265, 491, 523, 705, 903, 920, 942</sup>	n = 0	n = 187 <sup>9, 13, 21, 25, 31, 33, 41, 45, 48-50, 55, 56, 58, 62, 64, 66, 67, 72, 74, 80, 83, 86, 93, 97, 102, 104, 107, 111, 112, 116, 119, 122, 123, 129, 133, 139, 149-151, 155, 158, 161, 164, 169-172, 174-176, 180, 182, 186, 191, 193, 195, 199, 207, 208, 219, 227, 232, 233, 239, 241, 246, 248, 249, 252, 253, 256, 258, 270, 272, 276-278, 282, 291, 293, 294, 300, 302, 303, 309, 311, 314, 315, 320, 328, 332, 335, 337, 343, 346, 348, 359, 364, 365, 373, 374, 377, 382, 383, 386, 408, 412, 413, 416, 421, 425, 426, 444, 447, 452, 468, 469, 475, 477, 485, 488, 495, 505, 510, 518, 521, 522, 528, 530, 534, 539, 540, 562, 567, 573, 579, 600, 603, 627, 628, 663, 690, 725, 726, 728, 736, 739, 745-747, 749, 753, 755, 757, 779, 783, 785, 787, 788, 793, 797, 800, 803, 805, 806, 809, 826, 835, 837, 839, 841, 842, 847, 853, 866, 881, 891, 895, 904, 909, 918, 921, 944-946, 963</sup>	n = 86 <sup>8, 14, 15, 17, 23, 24, 34, 36, 43, 51, 53, 60, 61, 63, 79, 96, 98, 100, 101, 105, 106, 114, 120, 121, 128, 131, 135, 136, 166, 168, 175, 178, 184, 185, 190, 204, 223, 231, 235, 237, 242, 247, 264, 266, 284, 297, 298, 306, 310, 313, 324, 329, 338, 340, 353, 361, 362, 397, 410, 414, 417, 442, 449, 451, 453, 458, 465, 466, 525, 543, 599, 602, 625, 650, 655, 660, 695, 752, 757, 766, 784, 799, 811, 832</sup>
Bundle or unclear	n = 1 <sup>707</sup>	n = 0	n = 4 <sup>32, 511, 608, 949</sup>	n = 4
Total	n = 16	n = 2	n = 359	n = 103

Abbreviations: n, number of studies; RCT, randomized controlled trial.

The future systematic review may use the evidence from these mixed samples and a clinical practice guideline may use evidence from nonvascular but generally applicable fields. The identified intervention evaluations ranged the entire spectrum of ERAS approaches. Of note, only one study identified in the exploratory searches addressed a preadmission intervention specifically (a trial of “prehabilitation” that introduced exercises, nutritional counseling, and relaxation exercises 4 weeks before surgery).<sup>260</sup> However, some of the intervention bundles may contain preadmission components.<sup>59, 91, 325, 608, 949</sup>

We could not determine applicability for 2 studies because the full text was not available.<sup>137, 722</sup> We also identified a group of other ERAS research studies (n = 350).<sup>6, 7, 12, 16, 22, 28, 35, 37-39, 44, 47, 52, 54, 57, 68, 71, 76, 78, 82, 87, 90, 94, 95, 108, 113, 115, 117, 124, 126, 127, 132, 134, 138, 142, 144, 147, 148, 153, 154, 157, 159, 160, 162, 163, 165, 173, 179, 181, 189, 194, 196, 197, 200, 202, 205, 210, 212-218, 220, 222, 224, 226, 228-230, 234, 238, 244, 245, 250, 251, 257, 259, 261, 263, 267, 268, 271, 274, 275, 279-281, 283, 286, 287, 289, 290, 305, 307, 308, 317-319, 322, 323, 326, 327, 331, 333, 334, 339, 341, 342, 344, 345, 349, 355, 358, 360, 363, 366-372, 375, 378, 379, 384, 385, 387, 389-392, 394, 396, 398-400, 402, 403, 405, 406, 415, 418-420, 422, 429-432, 435-437, 439, 440, 443, 448, 454, 459-464, 470-472, 474, 478, 482, 484, 486, 487, 490, 492, 494, 496-498, 501, 503, 508, 509, 512, 514, 517, 526, 529, 531-533, 535-538, 541, 546-549, 552-554, 556, 558, 561, 563, 566, 569, 570, 575, 577, 580-582, 585, 586, 589, 590, 593, 594, 598, 601, 604, 606, 607, 610, 613-615, 617-619, 621-624, 631, 632, 634-637, 640, 641, 645, 649, 651-654, 656, 657, 664, 665, 669, 670, 674, 676, 677, 679, 680, 684, 688, 689, 691, 694, 696, 698, 699, 701, 706, 712, 719, 721, 724, 727, 729, 730, 732-734,</sup>

737, 738, 741, 743, 750, 751, 758, 760, 762-765, 767-776, 794-796, 798, 801, 802, 804, 807, 810, 815, 816, 818, 820, 823, 829, 836, 838, 851, 856, 857, 860-863, 870-875, 880, 893, 902, 908, 927, 932, 934, 935, 947, 951, 954, 958-960

However, based on the available information, we do not believe that the studies will be useful for a systematic review on ERAS in vascular surgery or helpful for a guideline specific to ERAS in vascular surgery. The studies addressed surgical procedures that were not vascular in nature or related to vascular surgery (such as open abdominal surgery) or were in samples with patient and/or operative characteristics that we deemed incompatible with vascular surgery, such as pediatric populations and otolaryngologic, orthopedic, gynecologic, and urologic operations that have no parallel in vascular surgery. Hence, the results of the incompatible studies would be difficult to apply to patients undergoing vascular surgery.

## Discussion

The topic brief documents the available literature on ERAS with emphasis on the available evidence for patients undergoing vascular surgery. We identified a large range of empirical studies on ERAS in general and found research evidence that appears to be suitable to be summarized in a systematic review to determine the effectiveness and comparative effectiveness of the available interventions in vascular surgery.

We applied an inclusive definition of ERAS to the existing literature so as not to miss research that may be relevant to particular aspects of a systematic review or practice guideline. In addition, research on patient recovery variables after surgery is evolving and encompasses a large field of very diverse approaches that aim to improve recovery from surgery. ERAS protocols span the entire care continuum; hence, there is a large number of potentially relevant approaches to enhance patients' recovery.

Despite the identified research literature, we also identified gaps in the vascular surgery research base for ERAS. Investigation of ERAS in vascular surgery does not appear to have kept pace with ERAS investigations in other surgical specialties. We identified a moderate number of ongoing studies that will become available in the near future. We did not identify a systematic review summarizing ERAS research for vascular surgery; however, subsequent to our literature search for this topic brief, an important review was published on ERAS for vascular operations.<sup>970</sup> Gaps in primary research were particularly apparent for research on preadmission interventions. Furthermore, not all interventions that have been tested in other surgical fields have sufficient evidence linking them to positive outcomes in vascular surgery (eg, early mobilization strategies). Hence, a future guideline for practitioners may need to draw on other sources of support, such as evidence from other surgical fields and/or expert opinion.

ERAS has had an important impact in other fields,<sup>1,971-976</sup> and patients undergoing vascular surgery are likely to benefit from a systematic review of the available evidence to formulate clinical practice guidelines for health care providers engaged in vascular surgery. Furthermore, we identified a number of strong study designs (ie, RCTs of ERAS evaluations) that support strong evidence statements. However, a topic brief can provide only an estimate of the existing literature, and a future systematic review will search additional sources and will likely find additional, potentially relevant literature. Conversely, the results of this topic brief are largely based on the title and abstract screening of the available literature. A systematic review will apply explicit inclusion and exclusion criteria to the full text of the publications, and some

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literature that appeared relevant based on the limited information available to us may not meet full-text inclusion screening criteria.

Although the evidence base on vascular surgery is still growing, a systematic review of the available literature appears to be feasible. The topic brief also indicates there is an opportunity for future research in ERAS for vascular surgery. For individual aspects of ERAS protocols, evidence from vascular surgery may need to be combined with research in mixed samples and ERAS protocol research applicable to vascular surgery. The results of the topic brief are only an estimate of the available literature.

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## Appendix A: Search Strategy

### PubMed

((“enhanced recovery after surgery”[title/abstract] OR “ERAS” [title/abstract] OR “enhanced recovery pathway”[title/abstract] OR post-operative recovery[title/abstract] OR “enhanced recovery pathways”[title/abstract] OR enhanced recovery protocol[title/abstract] OR (“enhanced recovery” AND “multimodal pathway”[title/abstract]) OR (“enhanced recovery” AND “multimodal pathways”[title/abstract]) OR (“enhanced recovery” AND surger\*[title/abstract]) OR (“ERAS” AND “multimodal pathway”[title/abstract]) OR (“ERAS” AND “multimodal pathways”[title/abstract]) OR (recovery AND perioperative pathways[title/abstract]))

OR (“enhanced recovery” OR fast track recovery[title/abstract] OR “accelerated recovery” OR “early recovery” OR “early discharge” OR accelerated recovery[title/abstract] OR rapid recovery[title/abstract] OR “early mobilization” OR vascular surgery[title/abstract]) AND (“care pathway”[title/abstract] OR “care pathways”[title/abstract]

OR (pre-admission AND intervention OR procedure) OR ((“patient education” OR “patient screening” OR patient expectation setting[title/abstract] OR “pre-conditioning” OR pre-habilitation” OR pre-operative exercise) AND (tobacco screening[title/abstract] OR alcohol screening[title/abstract] OR nutritional deficiency screening[title/abstract] OR frailty screening[title/abstract] OR anemia screening[title/abstract], OR diabetes screening[title/abstract] OR coronary artery disease screening[title/abstract] OR nutritional optimization[title/abstract]) OR (“medical screening” OR “medical optimization”[title/abstract]) OR “preadmission screening”[title/abstract] OR preadmission nutrition\*[title/abstract] “cognitive impairment screening”[title/abstract] OR “antiplatelet planning”[ALL FIELDS] OR (anticoagulation AND planning[title/abstract])

OR (“Preoperative intervention” OR “pre-operative intervention”[title/abstract]) OR (“Preoperative interventions” OR “pre-operative interventions”[title/abstract] OR preoperative protocol\*[title/abstract] OR pre-operative protocol\*[title/abstract] OR “preoperative preparation”[title/abstract] OR “pre-operative preparation”)

OR ((“limited fasting”[title/abstract] OR “recommended fasting” [title/abstract] OR (“carbohydrate loading”[title/abstract] AND diabetes[title/abstract]) OR “pre-emptive analgesia”[title/abstract] OR “Antiemetic Prophylaxis”[title/abstract] OR anti-emetic prophylaxis[title/abstract] OR antimicrobial prophylaxis[title/abstract] OR antimicrobial shower OR antimicrobial soap) AND (pre-operative OR preoperative))

OR “intraoperative intervention”[title/abstract] OR “intraoperative interventions”[title/abstract] OR intraoperative management[title/abstract] OR perioperative intervention OR perioperative interventions OR perioperative protocol\*[title/abstract] OR “anesthetic plan”[title/abstract] OR “anesthesia plan”[title/abstract] OR “regional anesthesia”[title/abstract] OR “neuraxial anesthesia”

OR (“post operative interventions” OR “post operative interventions”[title/abstract] OR “post operative” protocol\*[title/abstract] OR post-operative protocol\*[title/abstract] OR postoperative protocol[title/abstract]) OR “patient warming”[title/abstract] OR (“fluid management strategy” OR “fluid management strategies”[title/abstract]) OR (“multimodal analgesia” OR “opioid sparing analgesia” OR “multi modal analgesia”[title/abstract]) OR (“opioid minimization”[Title/Abstract]) AND (strategy[Title/Abstract] OR strategies[Title/Abstract]) OR

“drain management”[title/abstract] OR surgical drain[title/abstract] OR “line management”[title/abstract]  
OR early “drain removal”[title/abstract] OR early “line removal”[title/abstract] OR “foley catheter”[title/abstract] OR nasogastric tube\*[title/abstract] OR pulmonary toilet OR “early mobilization strategies”[title/abstract] OR “early mobilization”[title/abstract] OR (“diet regimen” OR “diet regimens”)[title/abstract] OR (“bowel regimen” OR “bowel regimens” OR anti-emetic)[title/abstract] OR ((plan OR plans OR planning) AND patient discharge[MESH]) OR (“discharge plan” OR “discharge plans” OR “discharge planning”)[title/abstract])  
AND  
 (“surgical procedure”[title/abstract] OR “surgical procedures”[title/abstract] OR Surgical Procedures, Operative[Majr] OR “vascular surgery”[title/abstract] OR “endovascular surgery”[title/abstract])  
AND  
(systematic review [publication type] OR (“clinical trial” OR “clinical trials”[title/abstract]) OR “Cohort Studies”[Majr] OR (“cohort study” OR “cohort studies”[title/abstract]) OR “case series”[title/abstract] OR “pre post”[title/abstract] OR “before after”[title/abstract] OR Controlled Before-After Studies[Majr] OR “time series”[title/abstract] OR (“randomized controlled trial” OR “randomized control trials”[title/abstract]) OR Randomized Controlled Trial [Publication Type] OR Randomized Controlled Trials as Topic[Majr] OR (“clinical trial” OR “clinical trials”[title/abstract]) OR Clinical Trial [Publication Type] OR Clinical Trials as Topic[Majr])

## CINAHL

“enhanced recovery after surgery” OR “ERAS” OR “enhanced recovery pathway” OR post-operative recovery OR “enhanced recovery pathways” OR enhanced recovery protocol OR (“enhanced recovery” AND “multimodal pathway”) OR (“enhanced recovery” AND “multimodal pathways”) OR (“enhanced recovery” AND surger\*) OR (“ERAS” AND “multimodal pathway”) OR (“ERAS” AND “multimodal pathways”) OR (recovery AND “perioperative pathways”)  
OR (“enhanced recovery” OR fast track recovery OR “accelerated recovery” OR “early recovery” OR “early discharge” OR “rapid recovery” OR “early mobilization” OR “vascular surgery”) AND (“care pathway” OR “care pathways” OR (“pre-admission” AND intervention OR procedure)  
OR (“patient education” OR “patient screening” OR “patient expectation setting” OR “pre-conditioning” OR “pre-habilitation” OR “pre-operative exercise”) AND (“tobacco screening” OR “alcohol screening” OR “nutritional deficiency screening” OR “frailty screening” OR “anemia screening” OR “diabetes screening” OR “coronary artery disease screening” OR “nutritional optimization”) OR “medical screening” OR “medical optimization” OR “preadmission screening” OR “preadmission nutrition\*” OR “cognitive impairment screening” OR “antiplatelet planning” OR (anticoagulation AND planning)  
OR “Preoperative intervention” OR “pre-operative intervention” OR “Preoperative interventions” OR “pre-operative interventions” OR “preoperative protocol\*” OR “pre-operative protocol\*” OR “preoperative preparation” OR “pre-operative preparation”  
OR (“limited fasting” OR “recommended fasting” OR “carbohydrate loading” AND diabetes)  
OR (“pre-emptive analgesia” OR “Antiemetic Prophylaxis” OR “anti-emetic prophylaxis” OR

“antimicrobial prophylaxis” OR “antimicrobial shower” OR “antimicrobial soap”) AND (“pre-operative” OR preoperative)  
OR “intraoperative intervention” OR “intraoperative interventions” OR “intraoperative management” OR “perioperative intervention” OR “perioperative interventions” OR “perioperative protocol\*” OR “anesthetic plan” OR “anesthesia plan” OR “regional anesthesia” OR “neuraxial anesthesia”  
OR “post operative interventions” OR “post operative interventions” OR “post operative protocol\*” OR “post-operative protocol\*” OR “postoperative protocol” OR “patient warming” OR “fluid management strategy” OR “fluid management strategies”  
OR (“multimodal analgesia” OR “multi modal analgesia” OR “opioid minimization” OR “opioid sparing analgesia”) AND (strategy OR strategies OR “drain management” OR “surgical drain” OR “line management” OR “early drain removal” OR “early line removal” OR “foley catheter” OR “nasogastric tube\*” OR “pulmonary toilet” OR “early mobilization strategies” OR “early mobilization” OR “diet regimen” OR “diet regimens” OR “bowel regimen” OR “bowel regimens” OR “anti-emetic” OR plan OR plans OR planning) AND (“patient discharge” OR “discharge plan” OR “discharge plans” OR “discharge planning”)  
AND  
“surgical procedure” OR “surgical procedures” OR “vascular surgery” OR “endovascular surgery”  
AND  
“clinical trial” OR “clinical trials” OR “Cohort Studies” OR “cohort study” OR “case series” OR “pre post” OR “before after” OR “Controlled Before-After Studies” OR “time series” OR “randomized controlled trial” OR “randomized control trials” OR “clinical trial” OR “clinical trials”

## Clinicaltrials.gov

Topics: ERAS, recovery

Context: Surgery, surgical procedures

Study designs: All ongoing studies that have stopped recruiting