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Prevalence of preoperative cognitive impairment in older surgical patients.: A systematic review and meta-analysis

Paras Kapoor, HBSc [a], Lina Chen, BSc [a], Aparna Saripella, MSc [a], Rida Waseem, MA [a], Mahesh Nagappa, MBBS [b], Jean Wong, MD [a,c], Sheila Riazi, MD MSc [a], David Gold, PhD [d], David F. Tang-Wai, MD CM [e], Colin Suen, MD PhD [a], Marina Englesakis, MLIS [f], Richard Norman, MD [g], Samir K. Sinha, MD DPhil [g], Frances Chung, MBBS. MD [a,*]

[a] *Department of Anesthesiology and Pain Medicine, Toronto Western Hospital, University Health Network, University of Toronto, Toronto, ON, Canada*
[b] *Department of Anesthesia & Perioperative Medicine, Western University, London, ON, Canada*
[c] *Department of Anesthesiology and Pain Medicine, Women's College Hospital, Toronto, ON, Canada*
[d] *Department of Psychiatry, University of Toronto, Toronto, ON, Canada*
[e] *Division of Neurology, Department of Medicine, University of Toronto, Toronto, ON, Canada*
[f] *Library & Information Services, University Health Network, Toronto, ON, Canada*
[g] *Division of Geriatric Medicine, Department of Medicine, University of Toronto, Toronto, ON, Canada*

A R T I C L E I N F O

Keywords:
Cognitive impairment
Surgery
Older patients
Prevalence
Preoperative assessment
meta-analysis

A B S T R A C T

Study objective: Older surgical patients with cognitive impairment are at an increased risk for adverse perioperative outcomes, however the prevalence of preoperative cognitive impairment is not well-established within this population. The purpose of this review is to determine the pooled prevalence of preoperative cognitive impairment in older surgical patients.
Design: Systematic review and meta-analysis.
Setting: MEDLINE (Ovid), PubMed (non-MEDLINE records only), Embase, Cochrane Central, Cochrane Database of Systematic Reviews, PsycINFO, and EMCare Nursing for relevant articles from 1946 to April 2021.
Patients: Patients aged ≥60 years old undergoing surgery, and preoperative cognitive impairment assessed by validated cognitive assessment tools.
Interventions: Preoperative assessment.
Measurements: Primary outcomes were the pooled prevalence of preoperative cognitive impairment in older patients undergoing either elective (cardiac or non-cardiac) or emergency surgery.
Main results: Forty-eight studies (n = 42,498) were included. In elective non-cardiac surgeries, the pooled prevalence of unrecognized cognitive impairment was 37.0% (95% confidence interval [CI]: 30.0%, 45.0%) among 27,845 patients and diagnosed cognitive impairment was 18.0% (95% CI: 9.0%, 33.0%) among 11,676 patients. Within the elective non-cardiac surgery category, elective orthopedic surgery was analyzed. In this subcategory, the pooled prevalence of unrecognized cognitive impairment was 37.0% (95% CI: 26.0%, 49.0%) among 1117 patients, and diagnosed cognitive impairment was 17.0% (95% CI: 3.0%, 60.0%) among 6871 patients. In cardiac surgeries, the unrecognized cognitive impairment prevalence across 588 patients was 26.0% (95% CI: 15.0%, 42.0%). In emergency surgeries, the unrecognized cognitive impairment prevalence was 50.0% (95% CI: 35.0%, 65.0%) among 2389 patients.
Conclusions: A substantial number of surgical patients had unrecognized cognitive impairment. In elective non-cardiac and emergency surgeries, the pooled prevalence of unrecognized cognitive impairment was 37.0% and 50.0%. Preoperative cognitive screening warrants more attention for risk assessment and stratification.

Abbreviations: BMI, body mass index; MCI, mild cognitive impairment; MMSE, Mini-Mental State Examination; MoCA, Montreal Cognitive Assessment; SRMA, systematic review and meta-analysis.

* Corresponding author at: Department of Anesthesia and Pain Medicine, Toronto Western Hospital, University Health Network, 399 Bathurst Street, Toronto, ON M5T 2S8, MCL 2-405, Canada.
E-mail address: frances.chung@uhn.ca (F. Chung).

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1. Introduction

Older adults, aged 60 years and over, account for nearly half of the 300 million surgical procedures performed annually [1,2]. As the fastest-growing age group worldwide, at least 40% of older adults will require surgery [2], and they are at a greater risk for perioperative complications [3]. Although relatively common among the older population with increasing age, cognitive impairment is an often unrecognized condition and is not routinely assessed preoperatively in older surgical patients [4]. Cognitive impairment encompasses a wide range of disorders that includes minimal or subjective decrements in cognition, mild cognitive impairment (MCI) that does not impact daily functioning, and dementia which is more severe and compromises daily functioning [5,6]. Cognitive impairment is associated with increased adverse peri-operative outcomes [7], including a decline in functional recovery, higher incidence of delirium, and higher hospital mortality. Establishing the prevalence of preoperative cognitive impairment among older surgical patients is useful to inform healthcare initiatives to better identify these patients before surgery to optimize medical treatment and avoid adverse outcomes [8].

The prevalence of perioperative neurocognitive disorders in older patients has been reviewed in specific surgical populations, such as vascular surgery populations [9,10]. The prevalence of preoperative cognitive impairment in older patients across a variety of elective and emergency surgeries has not been well-characterized. The primary objective of this systematic review and meta-analysis (SRMA) is to determine the pooled prevalence of preoperative cognitive impairment in older patients undergoing either elective (cardiac or non-cardiac) or emergency surgery.

2. Methods

The protocol of this SRMA was registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42021239344) and followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PRISMA checklist provided in Supplement as eTable1) [11]. The inclusion criteria were as follows: (1) patients aged greater than or equal to 60 years undergoing elective (cardiac or non-cardiac) or emergency surgeries; (2) patients evaluated preoperatively for preoperative cognitive impairment with validated screening instruments; (3) a comparison group of patients with no cognitive impairment; (4) randomised controlled trials (RCTs), observational studies (prospective and retrospective cohorts), and cross-sectional studies; and (5) English language. Case reports and case series were excluded. If participants had a prior diagnosis of cognitive impairment by neuropsychological battery, or clinical assessment before surgery, they would be designated as "diagnosed cognitive impairment". If patients did not have a prior diagnosis of cognitive impairment before study participation but performed in the cognitive impairment range on cognitive assessment tools, they would be suggested as "unrecognized cognitive impairment". Patients were differentiated based on the type of surgery into three groups: (1) elective non-cardiac, (2) elective cardiac, and (3) emergency surgeries. In elective non-cardiac surgeries, patients were divided into (1) mixed (multiple or single types of surgery), (2) orthopedic [spinal surgery/total hip arthroplasty (THA)/total knee arthroplasty (TKA)], and (3) vascular surgeries. In emergency surgeries, patients were divided into hip fracture and general surgeries. Patients were separated into these different surgical groups as previous research [12,13] has established that this is a meaningful classification to examine surgery-specific factors that may differentially impact prevalence of cognitive impairment. In the elective cardiac surgeries, all studies were in patients with unrecognized cognitive impairment, and in emergency surgeries, only two studies were in the "diagnosed cognitive impairment" group.

2.1. Search strategy

The following databases were searched from inception via the Ovid platform: Medline, Medline ePubs and In-Process Citations (daily), Embase, Ovid Emcare Nursing, and APA PsycINFO. The trial registry, ClinicalTrials.Gov (NIH), was also searched. All databases and trial registry were searched on the same day, December 18, 2020 The searching process followed the Cochrane Handbook [14] and the Cochrane Methodological Expectations of Cochrane Intervention Reviews (MECIR) [15] for conducting the search, the PRISMA guideline [11], and PRISMA-S extension for searches [16]. The PRESS guideline for peer-reviewing the search strategies [17], drawing upon the PRESS 2015 Guideline Evidence-Based Checklist, was used to avoid potential search errors. An updated search was done on April 8th, 2021, in which all databases and trial registry were searched on that same day, April 8th, 2021. This was done as Ovid MEDLINE underwent an update in January 2021, and to account for any new articles published between the two dates.

Preliminary searches were conducted, and full text literature was mined for potential keywords and appropriate controlled vocabulary terms (such as Medical Subject Headings for Medline and EMTREE descriptors for Embase). The Yale MeSH Analyser was used to facilitate the MeSH and text word analysis [18].

The search strategy concept blocks were built on the topics of: (Cognition or Cognitive Impairment) AND Preoperative AND (Elderly or Geriatric) AND Cognitive Assessment using both controlled vocabularies and text word searching for each component. Searches were limited to English language, humans, and elderly. Conference materials were removed from results at source. The Ovid Medline search strategy is provided in the Supplemental (eMethods).

2.2. Study selection and data extraction

Two reviewers (PK, AS) independently screened the studies for title and abstract eligibility using Rayyan (https://www.rayyan.ai/) [19]. Full text screening, data extraction, and quality assessment were independently performed by three reviewers (PK, LC, AS) and a senior reviewer (FC) resolved all the discrepancies. RW carried out the data analysis. We extracted data using standardized data collection sheets in Excel. Extracted data included author, country, publication year, study design, total number of patients, age, body mass index (BMI), gender, level of education, type of surgery, performance in cognitive impairment range, screening instruments for cognitive impairment, and their score.

2.3. Quality assessment of studies: Newcastle-Ottawa Quality Assessment Scale (NOS)

We used the Newcastle-Ottawa Quality Assessment Scale (NOS) for the quality assessment for case-control studies and cohort studies as well as the modified version for cross-sectional studies (eTable2) [20]. Two reviewers (AS, LC) independently critically appraised each included study. All conflicts were resolved by discussion with PK and FC. The NOS assessed the case-control and cohort studies for three components (selection, comparability, exposure/outcome) with eight question items and a maximum score of 9. We used the modified scale for cross-sectional studies assessed for the same three components with seven question items: representativeness of the sample, sample size, non-respondents, ascertainment of exposure, comparability of subjects in different outcome groups based on design or analysis, assessment of outcome, and statistical test. The total score of this scale was 10.

2.4. Data analysis

All statistical analysis was performed with the RStudio 1.4.1717 (RStudio, Boston, MA, United States) [21]. The pooled prevalence and 95% confidence interval (CI) were calculated for each category of

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surgery using a random effects DerSimonian and Laird method [22]. I^2 statistics were used to evaluate heterogeneity statistics. I^2 statistics with values of <30%, 30–60%, and > 60% represents low, moderate, and high levels of heterogeneity, respectively [23]. To assess the effect of covariates, meta-regression analysis was conducted with age, sex, BMI, study design, sample size, type of test, and country for each surgery category. Sex was selected as past research suggests differences between females and males in cognitive impairment prevalence [24–26]. The other variables were categorized as following: study design: prospective studies vs other studies (retrospective, cross-sectional, and secondary analysis); sample size: >100 vs ≤ 100 patients; type of test: neuropsychological tests and formal diagnosis vs screening tools; and countries: developed vs non-developed countries.

Sensitivity analysis or influential analysis was conducted to evaluate the effect of each study on the meta-analysis estimates. Each study was removed one at a time and estimates were calculated. A p-value of <0.05 was considered statistically significant. Publication bias was assessed by visually inspecting the funnel plots with 10 or more studies. Additionally, Egger's asymmetry test and Begg and Mazumdar rank correlation test were conducted [27,28].

3. Results

3.1. Search results and study characteristics

The demographic characteristics, prevalence, testing characteristics, and details of the different types of surgery are summarized in Tables 1. Mean age and BMI of the 48 studies were 74.8 ± 7.3 years and 26.5 ± 5.8 kg/m^2. A total of 8903 articles were identified and screened. Of the 121 full-text articles that were reviewed, 73 articles were excluded for reasons listed in Fig. 1. Forty-eight studies (n = 42,498) were included [29–76] with 42 studies in developed countries, while eight in non-developed countries. We included 32 prospective cohort studies, 11 retrospective cohort studies, four secondary analysis studies, and one cross-sectional study. Thirty-five studies were elective non-cardiac surgeries (25 unrecognized [29–53], 10 diagnosed [54–63]), four were elective cardiac surgeries (all unrecognized) [64–67], and six were emergency surgeries (five unrecognized [68–74], two diagnosed [75,76]). Twenty-two studies were classified as non-cardiac mixed surgery [29–44,54–59], 10 as orthopedic (spinal surgery/THA/TKA) [45–50,60–63], four as cardiac [64–67], three as vascular [51–53], and three as emergency general surgeries [72–74].

Twelve studies used the Montreal Cognitive Assessment (MoCA), eight used Mini-Mental State Exam (MMSE), nine used Mini-Cog, seven used different neuropsychological batteries, and the remaining twelve studies used a variety of screening methods (Tables 1-2). The cut-off values of cognitive impairment tests varied. For example, the MoCA cut-off used varied from 23 to 26. The prevalence of cognitive impairment ranged from 2.0% to 86.0%. Twenty-four studies reported data on age [30,33,34,36,39,41,44–46,48–50,54,56,58–61,64,65,70,72,74,75], 22 on gender [30,33,34,36,39,45,46,48–50,53,54,56,58,59,61,64,65,70,72,74,75], and 10 on BMI for the cognitive impairment group [30,34,36,39,45,46,48,49,54,60]. Fig. 2 illustrates the forest plots of the four categories of patients (elective non-cardiac surgery with unrecognized cognitive impairment, elective non-cardiac surgery with diagnosed cognitive impairment, elective cardiac surgery, and emergency surgery with both unrecognized and diagnosed cognitive impairment. Fig. 3 illustrates the forest plots of the surgical groups within the elective non-cardiac and emergency categories, and Fig. 4 illustrates the prevalence of these groups via a bar graph.

3.2. Unrecognized cognitive impairment in elective non-cardiac surgeries

Of the 48 included studies, 25 studies consisted of 27,845 patients undergoing elective non-cardiac surgeries (mixed, orthopedic, and vascular surgeries), and 7474 patients had unrecognized cognitive impairment [29–53]. Nineteen were prospective cohort [29–32,34,35,37,39–45,47,49,51–53] and five were retrospective cohort studies [33,36,38,48,50]; and one was a cross-sectional study [46]. For these 7474 patients, the mean age was 75.1 ± 7.1 years (Table 1).

In elective non-cardiac surgery, the pooled prevalence of unrecognized cognitive impairment was 37.0% (95% CI, 30.0%, 45.0%) (Fig. 2A). The forest plot displays non-overlapping confidence intervals, indicating high heterogeneity (I^2: 98%). The Beggs test was not significant (p = 0.950) but Egger's test of asymmetry showed significance indicating publication bias (p = 0.009). Visual inspection of funnel plots also indicated asymmetry. We conduced an influential analysis where each study was removed and the pooled estimate was recalculated, which did not show a significant difference in the inference of the pooled prevalence estimate.

For elective orthopedic surgery, the pooled prevalence of unrecognized cognitive impairment was 37.0% (95% CI, 26.0%, 49.0%) with high heterogeneity (I^2: 93%) (Fig. 3A). For elective vascular surgery, the pooled prevalence of unrecognized cognitive impairment was 64.0% (95% CI, 64.0%, 69.0%) with non-significant heterogeneity (I^2: 32%) (Fig. 3B).

3.3. Diagnosed cognitive impairment in elective non-cardiac surgeries

Nine studies consisted of 11,676 patients undergoing elective non-cardiac surgeries (mixed, orthopedic surgeries); 1225 of these patients were already diagnosed with cognitive impairment during preoperative assessments [54–63]. Three were prospective cohort [56,61–63] and three were retrospective cohort studies [57,58,60]; and three were secondary analyses [54,55,59]. The mean age of the diagnosed patients was 72.2 ± 8.2 years (Table 1).

In elective non-cardiac surgery, the pooled prevalence of diagnosed cognitive impairment was 18.0% (95% CI: 9.0%, 33.0%) with high heterogeneity (I^2: 99%) (Fig. 2B). Influential analysis did not show a significant difference in the inference of the pooled prevalence estimate. For orthopedic surgery, the pooled prevalence of diagnosed cognitive impairment was 17.0% (95% CI, 3.0%, 60.0%) with high heterogeneity (I^2: 100%) (Fig. 3C).

3.4. Unrecognized cognitive impairment in elective cardiac surgeries

Four studies consisting of 588 patients undergoing elective cardiac surgeries identified 125 patients with unrecognized cognitive impairment [64–67]. No study was found on patients with diagnosed cognitive impairment. Two were prospective cohort [64,65] and two were retrospective cohort studies [66,67]. The mean age was 67.9 ± 6.0 years (Table 2).

In elective cardiac surgery, the pooled prevalence of unrecognized cognitive impairment was 26.0% (95% CI: 15.0%, 42.0%) with high heterogeneity (I^2: 92%) (Fig. 2C). Influential analysis did not show a significant difference in the inference of the pooled prevalence estimate.

3.5. Unrecognized and diagnosed cognitive impairment in emergency surgeries

Nine studies included patients undergoing emergency surgeries (orthopedic and general surgery), consisting of 2389 patients; seven studies had 1572 patients with unrecognized cognitive impairment [68–74], and two studies had 105 patients that were diagnosed with cognitive impairment [75,76]. In one of the studies with diagnosed cognitive impairment, patients were formally diagnosed prior to study enrollment [76]. Seven studies were prospective cohort studies [68–73,75], one was a retrospective cohort study [76], and one was a secondary analysis study [74]. Among the cognitive impairment group (both unrecognized and diagnosed), the mean age was 79.3 ± 8.8 years (Table 2).

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Table 1
Demographics, prevalence, and testing characteristics of cognitive impairment patients undergoing elective non-cardiac surgeries.

Author, year	Study design	Type of surgery	Total patients (n)	Cognitive impairment prevalence (%)	Age (years) Mean ± SD	Male gender (%)	BMI (kg/m^2) Mean ± SD	Cognitive assessment tests and cut-off	Score of the tests Mean ± SD
Unrecognized Cognitive impairment									
Non-cardiac mixed surgery									
Kushner,[29] 2021 (USA)	PC	Hernia	70	34.3	N/A	N/A	N/A	Mini-Cog ≤3	N/A
Ristescu,[30] 2021 (Romania)	PC	Mixed	131	51.9	74.0 ± 6.3	42.7	25.8 ± 3.9	Mini-Cog ≤3	N/A
Amado,[31] 2020 (South Africa)	PC	Mixed	194	57.2	N/A	N/A	N/A	Mini-Cog ≤3	3.0 ± 1.5
Buckley, [32] 2020 (Australia)	PC	Mixed	102	24.5	N/A	N/A	N/A	4AT > 0	N/A
Gregory, [33] 2020 (USA)	RC	Mixed	21,666	23.5	75.5 ± 6.9	49.7	N/A	AD8 ≥ 2 SBT ≥ 5	N/A
Tong, [34] 2020 (China)	PC	Thoracic	154	49.4	69.8 ± 4.5	48.6	23.1 ± 4.2	MoCA <26	N/A
Pipanmekaporn, [35] 2020 (Thailand)	PC	Mixed	429	18.4	N/A	N/A	N/A	MSET10*	N/A
O'Reilly-Shah, [36] 2019 (USA)*	RC case-control	Mixed	1132	23.5	68.7 ± 9.7	42.5	29.0 ± 6.2	Mini-Cog ≤2	N/A
Samuelsson, [37] 2019 (Sweden)	PC	Colorectal cancer	49	8.2	N/A	N/A	N/A	MMSE <24	Median (IQR) 28 (3)
Banjongrewadee,[38] 2018 (Thailand)	RC	Mixed	429	2.8 [c] 12.6 [d]	N/A	N/A	N/A	MoCA <25	N/A
Miyata,[39] 2018 (Japan)	PC	Cataract	668	32.4	76.6 ± 5.0	51.2	22.9 ± 3.0	MMSE 24–26	N/A
Culley,[40] 2016 (USA)	PC	Mixed	198	Mini-Cog: 22.4 [e] CIB: 23.0 [f]	N/A	N/A	N/A	Mini-Cog ≤2	N/A
Smith,[41] 2016 (Australia)	PC	Mixed	215	DOSA: 60.2 PAC: 51.2	DOSA: 75.2[b] PAC: 76.7[b]	N/A	N/A	MoCA 19–25	N/A
Vichitveipaisal,[42] 2015 (Thailand)	PC	Mixed	582	GenVas:88.8 Uro: 81.5	N/A	N/A	N/A	MoCA <24	19.3 ± 4.61
Badgwell,[43] 2013 (USA)	PC	Abdominal	111	79.3	N/A	N/A	N/A	Mini-Cog, cutoff unspecified	N/A
Robinson,[44] 2012(USA) **	PC	Mixed	186	44.0	76.0 ± 6 0.0	N/A	N/A	Mini-Cog ≤3	N/A
Orthopedic (Spinal/THA/TKA) surgery									
Kim,[45] 2021 (South Korea)	PC	Spinal	102	47.0	72.4 ± 4.6	27.0	24.6 ± 3.0	MMSE-K < 26	N/A
Gan,[46] 2020 (China)	Cross-sectional	THA	374	28.6	73.3 ± 8.3	31.8	23.0 ± 3.5	MMSE****	16 ± 4.5
Susano,[47] 2020 (USA)	PC	Spinal	219	23.0	N/A	N/A	N/A	Mini-Cog ≤2	4.0 ± 1.5
Adogwa,[48] 2017 (USA)	RC	Spinal	82	69.5	74.7 ± 6.4	42.4	28.3 ± 6.7	SLUMS <27	N/A
Culley,[49] 2017 (USA)	PC	THA	211	23.7	76.0 ± 6.0	42.0	31.0 ± 7.0	Mini-Cog ≤2	N/A
Lee,[50] 2016 (South Korea)	RC	Spinal	129	38.0	72.9 ± 6.2	28.6	N/A	MMSE-K < 24	N/A
Vascular surgery									
Styra,[51] 2018 (Canada)	PC	Mixed vascular	173	68.8	N/A	N/A	N/A	MoCA <24	23.5 ± 4.2
Partridge,[52] 2015 (UK) ***	PC	Mixed vascular	125	61.6	N/A	N/A	N/A	MoCA <24	N/A
Partridge,[53] 2014 (UK) ***	PC	Mixed vascular	114	60.5	N/A	67.5	N/A	MoCA <24	22.0 ± 3.9
Diagnosed Cognitive Impairment									
Non-cardiac surgery									
Knaak,[54] 2020 (Germany)	secondary analysis	Mixed	934	8.2	71.3 ± 6.8	46.8	27.0 ± 5.3	Neuropsych <24 ≤ 2 SD	28.7 ± 2.3
Deiner,[55] 2018 (USA)	secondary analysis of PC	Mixed	120	34.2	N/A	N/A	N/A	Neuropsych 1 SD decline	27.8 ± 2.4
Racine,[56] 2018 (USA)	PC	Mixed	560	10.9	79.1 ± 6.7	48.0	N/A	Neuropsych + formal diagnosis	N/A
Sprung,[57] 2017 (UK)*	RC	Mixed	2014	15.7	N/A	N/A	N/A	Neuropsych N/A	N/A
Bekker,[58] 2010 (USA)	RC	Mixed	64	21.9	73.8 ± 6.9	43.0	N/A	GDS ≥ 3	N/A
Fritz,[59] 2020 (USA)	secondary analysis of RCT	Neuro	1113	38.6	70.3 ± 8.2	56.0	N/A	AD8 > 1 SBT > 4	N/A
Orthopedic (Spinal/THA/TKA) surgery									
Krishnan,[60] 2021 (USA)	RC	TKA	6350	1.98	75.8 ± 6.3	N/A	29.5 ± 5.9	Past records N/A	N/A
Hardcastle, [61] 2019 (USA)	PC	TKA	69	9.7	72.4 ± 8.2	53.8	N/A	Neuropsych < 1 SD in ≥2 tests	N/A
Silbert,[62] 2015 (Australia)	PC	THA	300	32.0	N/A	N/A	N/A	Neuropsych ≥2 SD	28.2 ± 1.23
Evered,[63] 2011 (Australia)	PC	THA	152	19.7 22.4	N/A	N/A	N/A	Neuropsych ≥1 SD decline on ≥2 tests	N/A

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Abbreviations: 4AT: 4 "A's" test; AD8: Ascertain Dementia 8-item Questionnaire; aMCI: amnestic mild-cognitive impairment; BMI: Body mass index; CIB: Clock-in-the-Box Test; DOSA: Day of surgery admission; EVAR: endovascular aneurysm repair; GDS: Global Deterioration Scale; GenVas: General/vascular; Uro: Urological; MMSE: Mini-mental state exam; MoCA: Montreal Cognitive Assessment; MSET10: Mental State Examination T10; N/A: Not available; PAC: Preadmission clinic; PC: Prospective cohort; RC: Retrospective cohort; RCT: Randomised controlled trial; SD: Standard deviation; IQR: interquartile range; SBT; Short Blessed Test; THA: Total hip arthroplasty; TKA: Total knee arthroplasty.
Data expressed as a: Median (IQR); b: Mean value; c: measured via MoCA; d: measured via MSET10; e: measured via Mini-Cog; f: measured via CIB.
Mixed surgery included: ventral or inguinal hernia, general, gynecological, neurosurgery, plastic, thoracic, general, oncologic, urological, colorectal cancer, cataract, non-neurological, abdominal, non-cardiac, other.
Mixed vascular surgery included: lower limb amputation, endovascular aneurysm repair, angioplasty, thrombolysis, thrombectomy, embolectomy, lower limb bypass, other.
* dependent on education: at least elementary: 22; no elementary: 17; illiterate: 14 ** consisted of a small number of cardiac surgeries. *** consisted of a small number of emergency surgeries. **** dependent on education: Illiterate: ≤ 17 Primary: ≤ 20 Middle: ≤ 24.

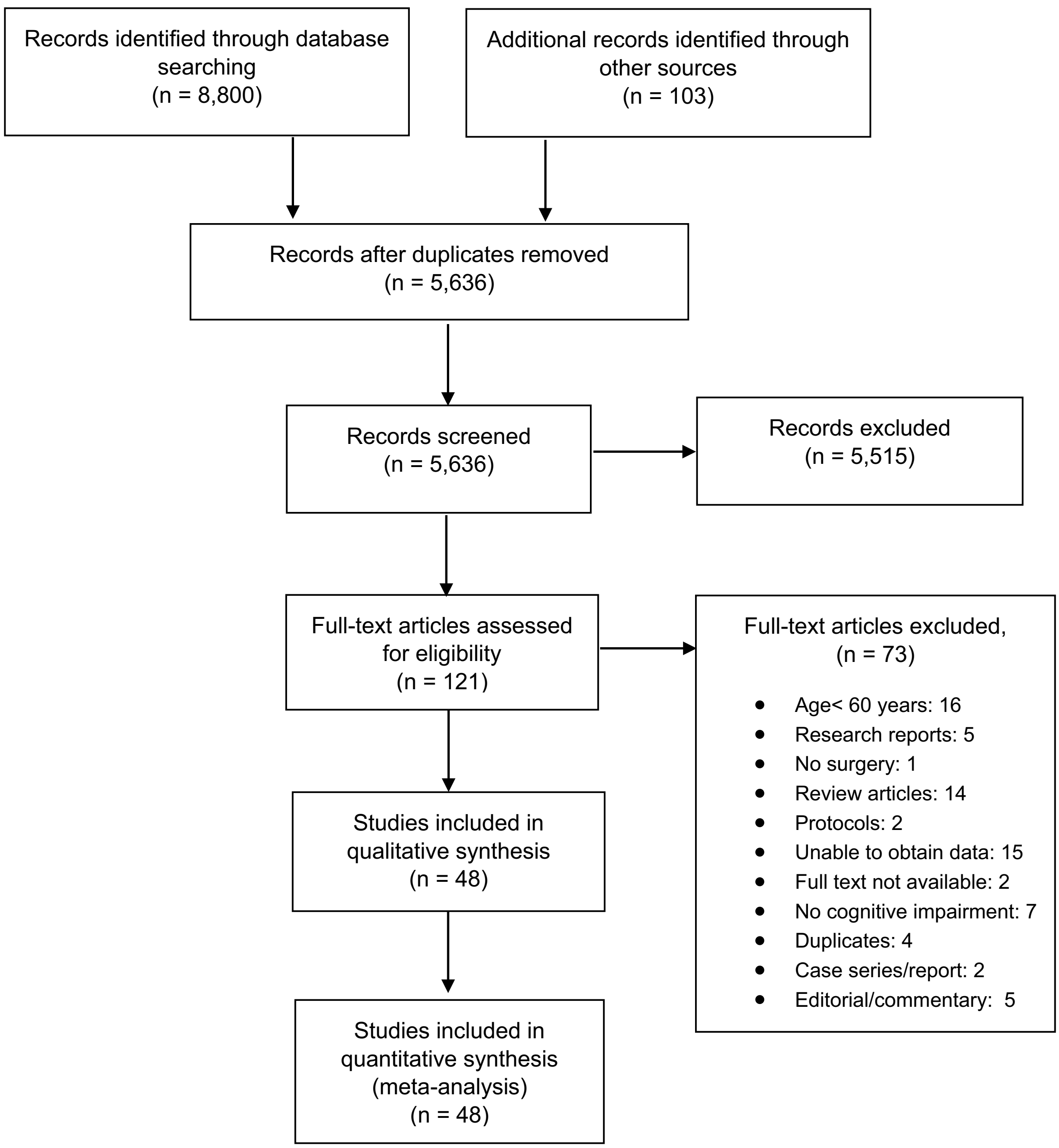

Fig. 1. PRISMA flow diagram of study selection.

In emergency surgery, the pooled prevalence of preoperative cognitive impairment (unrecognized and diagnosed) was 50.0% (95% CI: 35.0%, 65.0%) with higher heterogeneity (I^2: 98%). Influential analysis did not show a significant difference in the inference of the pooled prevalence estimate. For emergency orthopedic surgery, the pooled prevalence of unrecognized cognitive impairment was 49.0% (95% CI: 33.0%, 65.0%) with high heterogeneity (I^2: 96%) (Fig. 3D). For emergency general surgery, the pooled prevalence of unrecognized cognitive impairment was 64.0% (95% CI: 38.0%, 84.0%) with high heterogeneity (I^2: 98%) (Fig. 3E).

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Table 2
Demographics, prevalence, and testing characteristics of cognitive impairment patients undergoing cardiac and emergency surgeries.

Author, year (country)	Study design	Type of surgery	Total patients (n)	Cognitive impairment prevalence (%)	Age (years) Mean ± SD	Male gender (%)	BMI (kg/m^2) Mean ± SD	Cognitive assessment test and cut-offs	Score of the tests Mean ± SD
Unrecognized Cognitive Impairment Cardiac surgery									
Aykut,[64] 2013 (Turkey)	PC	CABG	48	52.1	70.2 ± 4.4	44.0	N/A	MoCA ≤23	N/A
Bendikaite,[65] 2020 (Lithuania)	RC	CABG, valvular	245	24.1	66.9 ± 6.3	46.9	N/A	MMSE ≤20	N/A
Lingehall,[66] 2017 (Sweden)	PC	Mixed	114	7.9	N/A	N/A	N/A	MMSE <24	26.6 ± 3.9
Harrington,[67] 2011 (USA)	RC	Mixed	181	32.6	N/A	N/A	N/A	CIB ≤ 5	N/A
Unrecognized Cognitive Impairment Emergency hip fracture surgery									
Rocío Menéndez-Colino,[68] 2018 (Spain)	PC	Hip fracture	509	47.9	N/A	N/A	N/A	SPMSQ >3	N/A
Bliemel,[69] 2015 (Germany)	PC	Hip fracture	399	66.9	N/A	N/A	N/A	MMSE ≤26	N/A
Daniels,[70] 2014 (USA)	PC	Hip fracture	65	62.9	82.8 ± 7.5	30.8	N/A	MoCA ≤23	N/A
Kaganksy,[71] 2004 (Israel)	PC	Hip fracture	102	23.5	N/A	N/A	N/A	MMSE <24	N/A
Emergency general surgery									
Hanna,[72] 2021 (South Korea)	PC	General surgery	142	20.0	73.5 ± 7.8	72.0	N/A	MoCA <26	N/A
Ablett,[73] 2018 (UK)	PC	General surgery	539	84.4[a] 61.0[b]	N/A	N/A	N/A	MoCA[a]: ≤ 26 MoCA[b]: ≤ 23	N/A
Hewitt,[74] 2014 (UK)	Secondary analysis from a PC	General surgery	201	81.6	77.4 ± 7.8	41.4	N/A	MoCA ≤26	N/A
Diagnosed Cognitive Impairment									
Larsson,[75] 2019 (Sweden)	PC	Hip fracture	318	21.0	84.3 ± 9.1	25.0	N/A	SPMSQ ≤7	N/A
Levinoff,[76] 2018 (Canada)	RC	Hip fracture	114	32.5	N/A	N/A	N/A	Formal diagnosis	N/A

Abbreviations: BMI: Body mass index; CABG: Coronary artery bypass graft; CIB: Clock-in-the-Box Test; MMSE: Mini Mental State Exam; MoCA: Montreal Cognitive Assessment; N/A: Not available; PC: Prospective cohort; RC: Retrospective cohort; SPMSQ; Short portable mental status questionnaire; SD; standard deviations.
a: traditional MoCA; b: Proposed MoCA
Mixed surgery included: CABG, valvular, combined procedures.

3.6. Meta-regression

To examine the effect of age, gender, BMI, study design (prospective vs. others), sample size (≤ 100 vs. >100), type of test (neuropsychological tests and formal diagnosis vs. others), and country (developed vs. others) on pooled prevalence as appropriate, a meta-regression analysis was conducted for categories as described in Fig. 2 and Fig. 3. For elective non-cardiac surgery, analysis showed that there was a significant positive relationship between pooled prevalence of cognitive impairment and prospective cohort studies when compared to studies with other designs ($\beta = 0.903$, 95% CI: 0.211–1.595, $p = 0.011$). We found a higher prevalence of unrecognized cognitive impairment in prospective design studies. No significant interaction was observed for other covariates (age, gender, BMI, study design, sample size, type of test, and country) or other surgery categories.

3.7. Quality assessment

Quality assessment of the included studies are presented in eTable 2 of the supplementary. The score ranged from 4 to 9 for cohort studies, 9 for case-control studies and 8 to 9 for cross-sectional studies. The studies scored well in the domains of representativeness of the exposed cohort, ascertainment of exposure, follow-up for outcomes, adequacy of follow-up of cohorts, ascertainment of exposure, non-response rate, and statistical tests. Many studies did not provide an explanation for their accounting for risk factors, adjustment for education, assessment of outcome, and sample size.

4. Discussion

In this SRMA of 48 studies, we found that preoperative cognitive impairment is common in older patients undergoing both elective and emergency surgeries. In elective non-cardiac surgeries, the pooled prevalence of unrecognized cognitive impairment was 37.0% among 27,845 patients and diagnosed cognitive impairment was 18.0% among 11,676 patients. In cardiac surgeries, the unrecognized cognitive impairment prevalence across 588 patients was 26.0%. In emergency surgeries, the cognitive impairment prevalence (unrecognized and diagnosed) was 50.0% among 2389 patients.

For patients undergoing elective vascular and orthopedic surgery, we found that the prevalence of unrecognized cognitive impairment was 64.0%, and 37.0%, respectively. Consistent with the literature [12], we found that the overall pooled prevalence of unrecognized cognitive impairment in vascular surgical patients is high. Some important risk factors to consider for peripheral vascular disease are hypertension and hyperlipemia, as well as their association with cardiovascular and cerebrovascular disease, as these may predispose individuals to vascular cognitive impairment [12,13].

Studies on spinal surgeries [45,47,48,50] showed higher prevalence values compared to hip and knee surgeries [46,49,60–63]. Certain

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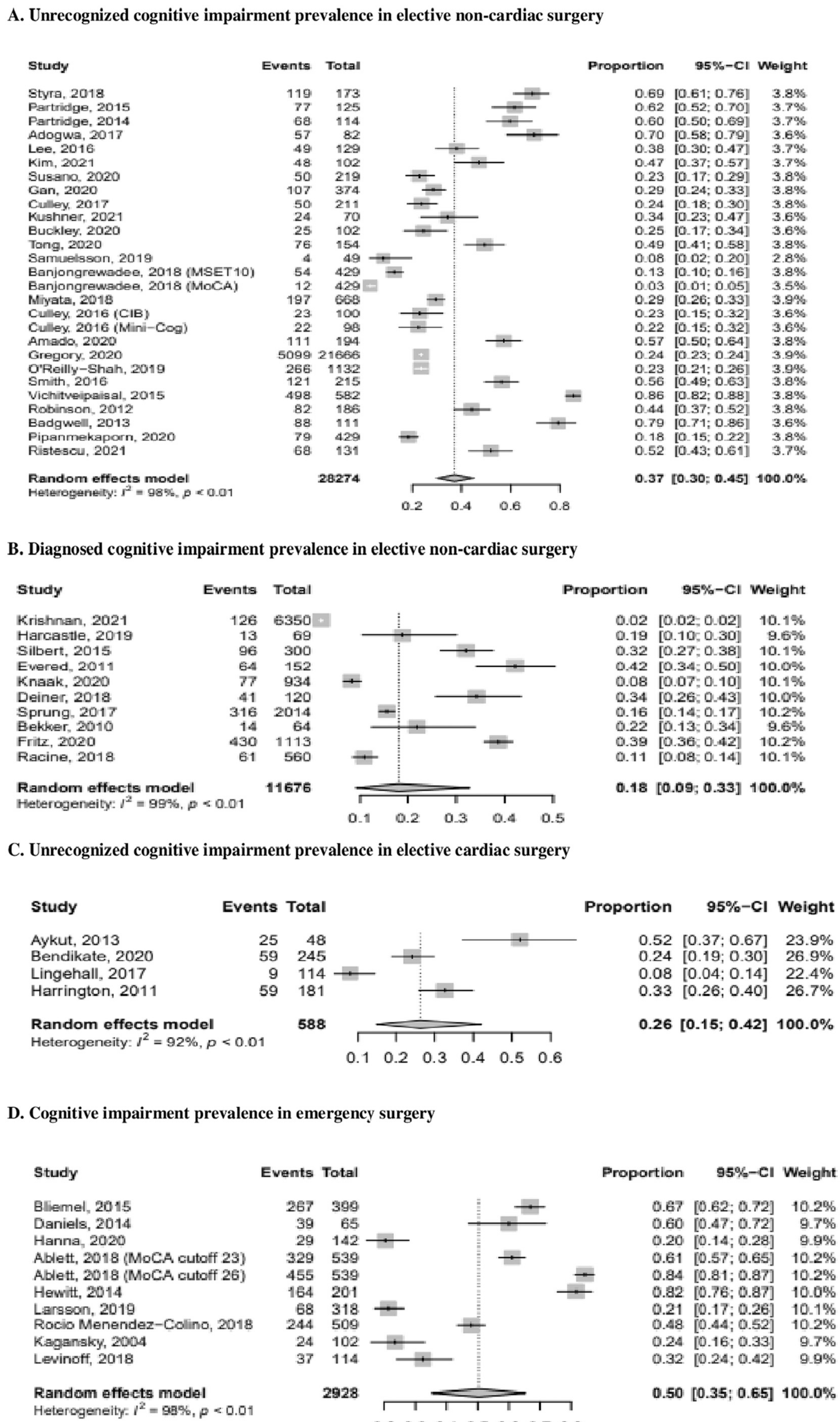

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Fig. 2. Forest plot for the pooled prevalence of cognitive impairment across different surgery types. Heterogeneity values I^2 are stated for elective non-cardiac surgery, elective cardiac surgery, and emergency surgery. Banjongrewadee (2018) and Culley (2016) both used two separate tools to calculate two separate prevalence values, with the test used shown in brackets beside those two studies. The forest plot of emergency surgery is composed of both unrecognized and diagnosed cognitive impairment. Non-cardiac surgery included: mixed surgery, orthopedic (spinal surgery/THA/TKA) surgery, and vascular surgery; Emergency surgery: hip fracture surgery and general surgery; CI: confidence interval; Events: patients with cognitive impairment; MoCA: Montreal cognitive assessment; CIB: Clock-in-the-Box Test; MSET10: Mental State Examination.

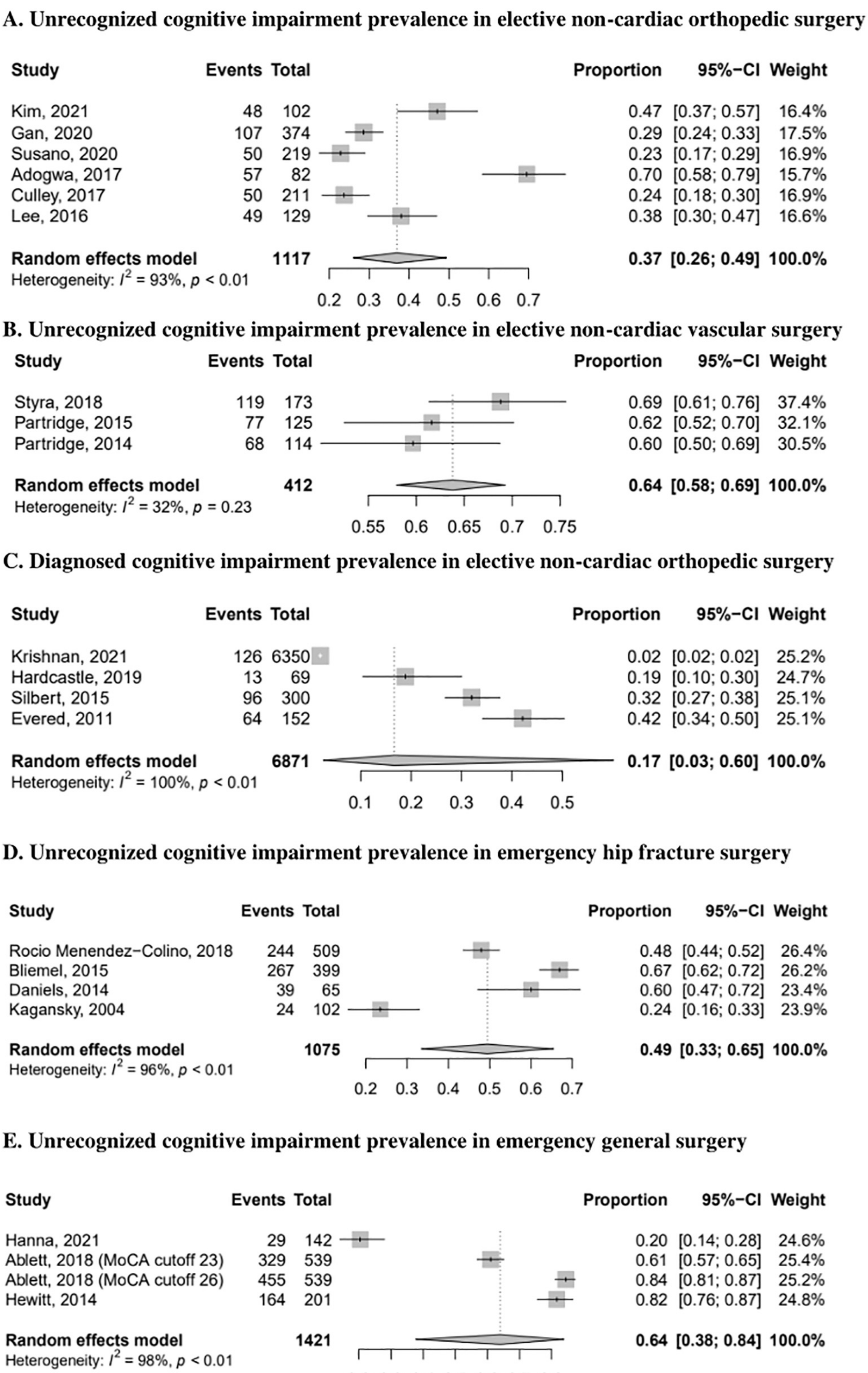

Fig. 3. Forest plot for the pooled prevalence of cognitive impairment across individual surgery categories within each main group. Elective orthopedic surgery: spinal surgery/ Total hip arthroplasty / Total knee arthroplasty; Emergency orthopedic surgery: hip fracture surgery. Cardiac surgery not shown as it was not divided into separate surgery types. Heterogeneity values I^2 are stated for each group; CI: confidence interval; Events: patients with cognitive impairment; MoCA: Montreal cognitive assessment.

A. Prevalence of unrecognized cognitive impairment in elective orthopedic surgery.

B. Prevalence of unrecognized cognitive impairment in elective vascular surgery C. Prevalence of diagnosed cognitive impairment in elective orthopedic surgery.

D. Prevalence of unrecognized cognitive impairment in emergency orthopedic surgery.

E. Prevalence of unrecognized cognitive impairment in emergency general surgery.

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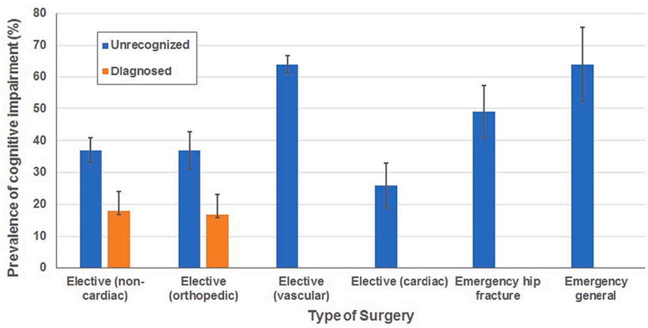

Fig. 4. The prevalence of cognitive impairment in older surgical patients in different surgery categories. Vertical lines over the bar represent standard error. Elective non-cardiac surgery: mixed surgery, orthopedic surgery, vascular surgery. Elective orthopedic surgery: spinal surgery/total hip arthroplasty/total knee arthroplasty.

spinal disorders, such as adult degenerative scoliosis, have been associated with a decline in cognition, and spinal injuries are associated with a range of factors that may contribute to cognitive impairment [48,77]. Further research could examine the effect of vascular risk factors, medications, or the debilitating impact of these injuries on the quality of life.

We found the pooled prevalence in emergency surgeries (unrecognized and diagnosed) was high at 50.0%. Factors such as fear and anxiety in an unfamiliar environment, acute stressors, pain at baseline, sudden injury, and associated delirium may have influenced preoperative cognitive testing scores [69,70,78].

One mixed surgery (elective surgery with patients with unrecognized cognitive impairment) study found a high prevalence value (85.6%), which could be attributed to the inclusion of vascular surgery patients with mostly low levels of education resulting in lower MoCA scores, highlighting the need for education-adjusted norms [42]. The cognitive assessment tool, MoCA, has been suggested as being the most appropriate for detecting MCI given its superior sensitivity and specificity of 89% and 75% compared to the MMSE (sensitivity 62%; specificity 87%) [79,80]. However, the MoCA is biased towards verbal communication and its validity can be affected by education, language, and cultural diversity [81,82]. There are education adjustments for most validated cognitive screening tools. While studies in this SRMA did discuss these adjustments with the tools used, only nine-studies in our SRMA reported education data for the cognitively impaired group [39,42,46,49,50,53,58,61,65]. In two studies that reported a low prevalence of unrecognized cognitive impairment, a comprehensive neuropsychological test battery and strict definition of a cognitive impairment diagnosis were employed [54,60]. While these methods have better diagnostic accuracy, they are time-consuming and resource intensive.

Cognitive screening tools are helpful in identifying potential cognitive impairment, but a poor score may not properly account for contributing factors such as mood or medical conditions that impact performance. The determination of cognitive impairment in many of these studies was based on cognitive testing, but performance may not properly account for contributing factors that influence cognitive assessment such as education, language, and cultural differences [81]. Recent research proposes to unite the nomenclature of cognitive decline in psychiatry and geriatrics. Evered et al discussed the importance of using updated nomenclature to enhance communication and reporting of cognitive decline, and the importance of using objective criteria (i.e., data that is comparable to population norms, such as that collected by neuropsychological batteries) to diagnose cognitive impairment, versus the use of screening tools such as the MMSE and MoCA [83]. To determine if a person has MCI or dementia, clinical evaluation is needed. A healthcare professional knowledgeable in cognitive impairment is needed to analyze all potential influences on a patient's performance to clarify whether a diagnosis of MCI or dementia is warranted. Nonetheless, the relatively high prevalence of abnormal cognitive assessment emphasizes the importance of routine preoperative cognitive assessment in older surgical patients.

For elective non-cardiac surgeries, our meta-regression showed that there was a strong positive association between prevalence of cognitive impairment and prospective cohort design versus other designs. Most studies that were not prospective (i.e., retrospective, cross-sectional etc.) fell under 'diagnosed cognitive impairment' using stricter methods of assessing cognitive impairment. This is in comparison to screening tools that may provide over-inflated recognition of cognitive impairment.

4.1. *Utility of preoperative cognitive screening in practice*

Preoperative cognitive screening of older surgical patients is valuable for risk assessment and stratification. As populations with a high prevalence of unrecognized cognitive impairment, screening of vascular and emergency surgery patients could prove especially beneficial. Identifying at-risk individuals could have various benefits such as: (1) early diagnosis and management of reversible cognitive impairment (i.e. low hormone levels, vitamin B12 deficiency, mood disorders) and non-reversible impairment (dementia) could allow for better long term patient and system outcomes; (2) counseling expectations and possible risks for an informed decision about the proposed surgery; (3) influencing care management such as approach to types of anesthetics, medications, and improved postoperative pain control; (4) providing an alternative surgical approach, and (5) providing better monitoring and follow-up appointments.

Cognitive impairment is a leading risk factor for the development of postoperative delirium. Early detection and management of postoperative delirium is critical [84]. Additionally, treatment of underlying cognitive impairment may treat neuropsychiatric symptoms which is beneficial for cognitive and physical functioning, and can provide a long-term management plan to effectively recover once the surgical episode is over [85]. Although the American Society of Anesthesiologists Brain Health Initiative Summit (2018) and Global Council on Brain Health (2020) recommend preoperative evaluation of cognitive function in older patients, this practice has not been widely implemented [86,87].

4.2. *Limitations*

Some limitations of our SRMA exist. First, retrospective observational cohort studies were included and they are prone to various biases. Second, many studies did not report on BMI, education level, and other risk factors, which can act as potential confounders. In our SRMA, we did not include any studies on patients < 60 years old. The average age is approximately 75 years, which is well into the older age range and may be the explanation why age was not a predictor. Third, selection bias, observer bias, and variations in outcome definitions may have introduced possible bias in the pooled prevalence estimates. Our findings showed high levels of heterogeneity, likely because the included studies were geographically, clinically, and methodologically diverse such as different cognitive assessment tools.

5. Conclusion

Our findings highlight the high prevalence of cognitive impairment in older surgical patients and their unmet needs. Importantly, a substantial number of patients present for surgery when their cognitive impairment is unrecognized. In elective non-cardiac surgeries, and emergency surgery, the pooled prevalence of unrecognized cognitive impairment was 37.0% and 50.0%. As our population continues to age with increasing surgical needs and considering the substantial prevalence of undetected cognitive impairment, more rigorous cognitive

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screening should be incorporated into preoperative assessment. Preoperative cognitive screening warranted more attention as it may be valuable for risk assessment and stratification.

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Author contributions

Study concept and design: PK, AS, FC. Literature search: ME. Acquisition, analysis, and interpretation of data: PK, RW, AS, MN, FC. Writing of manuscript: PK, AS, LC, RW, FC. Critical review and approval of manuscript: all authors. FC guarantees the integrity of the work.

Paras Kapoor and Frances Chung had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Declaration of Competing Interest

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