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A Review of the Cost-Effectiveness of Frailty-Based Preoperative Assessment in Coronary Artery Bypass Grafting Patients

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KEYWORDS

Coronary artery bypass grafting, Percutaneous coronary intervention, Preoperative assessment, Cost-effectiveness, Decision-analytic models, Postoperative outcomes

ABSTRACT:

Background: Coronary artery bypass grafting (CABG) remains the gold standard for the management of complex coronary artery disease despite advances in percutaneous coronary intervention. As the surgical population becomes increasingly older and medically complex, frailty has emerged as an important predictor of postoperative morbidity, mortality, prolonged hospitalization, and healthcare costs. Evaluating the clinical and economic value of incorporating frailty assessment into routine preoperative care is therefore of growing importance.

Objective: To review the current evidence on the role of frailty assessment in patients undergoing CABG, with particular emphasis on its impact on clinical outcomes, risk stratification, and cost-effectiveness.

Methods: A comprehensive review of the published literature was conducted using peer-reviewed studies addressing frailty assessment, CABG outcomes, and economic evaluation. Relevant evidence on epidemiology, frailty assessment tools, perioperative outcomes, healthcare resource utilization, and cost-effectiveness was synthesized to provide an integrated overview of current knowledge.

Results: Frailty was consistently associated with increased postoperative complications, prolonged intensive care and hospital stays, higher readmission rates, impaired functional recovery, and increased short- and long-term mortality following CABG. Validated frailty assessment instruments, including phenotype- and deficit-based models and the Risk Analysis Index, improved preoperative risk stratification beyond conventional surgical risk scores. Evidence also indicated that routine frailty screening facilitates individualized perioperative management, targeted prehabilitation, and optimized resource allocation. Economic evaluations suggest that incorporating frailty assessment into preoperative pathways is a cost-effective strategy by reducing postoperative complications, shortening hospital stay, and improving quality-adjusted life years while lowering overall healthcare expenditure.

Conclusion: Frailty is a significant independent determinant of outcomes after CABG and should be incorporated into routine preoperative evaluation. Integrating validated frailty assessment tools into clinical practice may improve patient selection, enhance perioperative decision-making, optimize healthcare resource utilization, and provide both clinical and economic benefits. Further prospective multicentre studies are required to establish standardized frailty assessment protocols and strengthen the evidence supporting their routine implementation in cardiac surgery.

1. Introduction

Coronary artery disease remains one of the leading causes of morbidity and mortality worldwide [1]. It results from atherosclerotic narrowing or occlusion of the coronary arteries, leading to reduced myocardial perfusion. Among available treatment strategies, coronary artery bypass grafting is widely used for patients with severe or multivessel disease, particularly when optimal medical therapy and percutaneous coronary intervention are insufficient to achieve adequate revascularization [2,3].

CABG involves the surgical construction of alternative conduits commonly using the internal mammary artery, radial artery, or saphenous vein to bypass obstructed coronary segments and restore blood flow to the myocardium. The procedure has been shown to improve survival, relieve angina, and enhance quality of life [2,4]. Although the global volume of CABG procedures has declined somewhat in recent years owing to the rapid evolution of PCI, CABG remains the most commonly performed form of cardiac surgery worldwide [5,6]. However, the clinical profile of the "typical" CABG candidate has changed considerably over the past few decades. Patients presenting for surgery today are older and carry a greater burden of comorbidity, including diabetes mellitus, hypertension, chronic kidney disease, and heart failure all of which add complexity to both the operative course and postoperative recovery [7].

One factor that has emerged as a critical determinant of how well a patient tolerates and recovers from surgery is frailty [8]. Frailty is not synonymous with chronological age; rather, it denotes a biological state of diminished physiological reserve that leaves an individual disproportionately vulnerable to physical stressors [9]. Clinically, it manifests as reduced strength and endurance and an impaired capacity of the body to recover after an insult [8]. Recent studies suggest that up to 60% of elderly patients presenting for CABG may be frail for these patients, the perioperative course is frequently complicated by infection, prolonged ventilatory dependence, delirium, and even death [10]

Because of these risks, preoperative recognition of frailty has assumed growing clinical importance. Frailty assessment allows clinicians to more accurately characterize a patient's fitness for surgery, thereby supporting shared, well-informed treatment decisions [11]. Beyond its clinical value, frailty assessment may also yield meaningful economic benefits, as identifying at-risk patients early can reduce downstream healthcare expenditure through better-targeted perioperative optimization and resource allocation [12]. For these reasons, evaluating the cost-effectiveness of frailty-based preoperative assessment in CABG is an important and timely undertaking, as it helps establish whether such interventions yield sufficient clinical and economic benefit to justify their routine adoption [12,13].

2. Importance of CABG in Modern Cardiac Care

Despite the expanding role of less invasive revascularization techniques and continued advances in medical therapy, CABG retains a central place in the management of advanced coronary artery disease and remains the most frequently performed cardiac operation worldwide [14]. It is particularly beneficial for patients with complex multivessel disease, diabetes mellitus, or left ventricular dysfunction, in whom surgical revascularization has been shown to confer more durable outcomes and a lower need for repeat procedures compared with PCI [15]. Long-term outcome data continue to support this survival and durability advantage in appropriately selected patients, a pattern echoed in large national cardiac surgery database reports [16].

Importantly, the benefits of CABG are contingent on appropriate patient selection and a thorough preoperative workup. As the population ages, an increasing proportion of patients presenting for cardiac surgery are elderly and carry substantial comorbid disease burden, underscoring the need for preoperative evaluation strategies that extend beyond conventional risk models [17].

3. Frailty Assessment in Preoperative Evaluation

Conventional surgical risk-prediction models such as the European System for Cardiac Operative Risk Evaluation (EuroSCORE) have traditionally focused on chronological age, comorbid disease, and cardiac function [15,18]. While informative, these models do not adequately capture the physiological vulnerability that characterizes frailty. To address this gap, several dedicated frailty assessment instruments have been developed and validated in surgical populations.

Two conceptual frameworks underlie most of these tools: the physical phenotype model, which characterizes frailty through measurable deficits such as slow gait speed, weak grip strength, unintentional weight loss, exhaustion, and low physical activity, and the deficit-accumulation model, which quantifies frailty as the cumulative burden of age-related health deficits across multiple domains [19]. Building on these frameworks, instruments such as the Risk Analysis Index (RAI) incorporate age, functional status, weight loss, comorbidity, and cognitive impairment into a composite frailty score [20]. Incorporating structured frailty assessment into routine preoperative evaluation allows surgical teams to better stratify risk, individualize perioperative planning, and potentially reduce postoperative complications [19,21].

4. Epidemiology of Frailty in CABG Patients

Frailty is increasingly recognized as a clinically important entity among patients undergoing CABG, reflecting reduced physiological reserve and heightened susceptibility to the physiological stress of surgery [22]. Interest in its epidemiology has grown substantially in recent years, driven largely by the demographic shift toward an older surgical population [23]. Reported prevalence varies considerably across studies, ranging from approximately 20% to 50%, and is particularly high among patients older than 65 years, a pattern consistent with the natural age-related decline in muscle strength, mobility, and cognitive function [24]. Additional contributors to frailty in this population include multiple coexisting conditions such as diabetes mellitus, hypertension, chronic kidney disease, chronic obstructive pulmonary disease, and heart failure [25].

The epidemiological significance of frailty in CABG populations stems largely from its strong association with adverse surgical outcomes [10]. Frail patients face a markedly elevated risk of infection, acute kidney injury, cerebrovascular events, prolonged ventilatory support, and impaired wound healing [26,27]. Frailty has also been shown to independently predict operative and long-term mortality after cardiac surgery, even after adjustment for conventional risk factors [28]. In addition, frailty is associated with longer hospital and intensive care unit stays and higher readmission rates relative to non-frail patients, all of which add measurably to the burden borne by healthcare systems [29].

Frailty prevalence among CABG patients also appears to vary by demographic and socioeconomic factors. Several studies report higher frailty scores among women than men, potentially reflecting differences in muscle mass, nutritional status, and comorbidity profile [22,30]. Socioeconomic determinants, limited access to healthcare, poor nutritional status, and physical inactivity, have similarly, been linked to a higher risk of frailty, and geographic variation in prevalence has been reported, likely reflecting regional differences in the burden of comorbid disease among aging populations [31].

From a public health perspective, the growing recognition of frailty among CABG candidates highlights the importance of early detection and proactive management [10]. Incorporating frailty assessment into the standard preoperative evaluation supports a more individualized approach to care, potentially including targeted nutritional support, prehabilitation and physical therapy, and adjustment of surgical timing according to a patient's physiological readiness [32]. Such strategies may improve patient outcomes while reducing the broader burden of disease on healthcare systems.

5. Clinical Significance of Frailty in CABG

Frailty has a well-documented association with both short- and long-term mortality following CABG [33]. Multiple clinical studies demonstrate that frail patients experience substantially higher mortality than their non-frail counterparts, and, critically, this association persists even after adjusting for established risk factors such as age, comorbidity, and cardiac function [34]. This independent predictive value underscores the importance of incorporating frailty assessment into routine preoperative risk stratification, alongside validated instruments such as the Clinical Frailty Scale [35].

Frailty is also strongly associated with prolonged hospitalization. Frail patients typically require longer stays in intensive care and general wards, largely reflecting delayed recovery and a higher complication burden [36]. Beyond the acute postoperative period, frail patients often experience persistent limitations in mobility and activities of daily living, as well as an elevated risk of postoperative neurocognitive decline, which can meaningfully affect long-term quality of life [37].

From a health-system perspective, the association between frailty and adverse CABG outcomes translates directly into increased resource utilization, longer hospital stays, higher readmission rates, and greater requirements for intensive postoperative care, all of which increase the overall cost of treatment [38]. This consistent link between frailty and resource use is a central justification for incorporating structured frailty screening into preoperative pathways [13].

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6. Parameters Relevant to Frailty and CABG Outcomes

6.1 Demographic Parameters

Demographic characteristics form an essential baseline in understanding outcomes after CABG. These include patient age, sex, body mass index, smoking status, and socioeconomic background [39]. Age is of particular importance, as advancing age is strongly associated with increasing frailty and, in turn, a more complicated recovery trajectory [40]. Sex-related differences in cardiovascular physiology, body mass index as a marker of nutritional reserve, and smoking history as a determinant of cardiovascular risk each contribute additional, independent influence on recovery [41]. Collectively, these findings support the integration of frailty assessment alongside conventional demographic risk factors to improve outcome prediction after CABG.

6.2 Clinical Parameters

Clinical parameters describe the burden of coexisting disease in patients undergoing CABG, including hypertension, diabetes mellitus, chronic kidney disease, chronic obstructive pulmonary disease, and prior myocardial infarction, as well as left ventricular ejection fraction as a marker of cardiac function [42]. Patients with a greater burden of comorbidity are at higher risk of postoperative complications and are more likely to incur higher healthcare costs [43]. Evaluating these clinical parameters alongside frailty status provides a more complete picture of overall surgical risk and supports individualized treatment planning [44].

6.3 Frailty Assessment Parameters

Frailty assessment parameters are intended to capture a patient's physiological vulnerability before surgery. Physical parameters include gait speed, grip strength, exhaustion, unintentional weight loss, and low physical activity [12]. Functional parameters, including basic and instrumental activities of daily living, capture a patient's capacity for independent function [45]. Cognitive status and nutritional indices, such as serum albumin, further refine the preoperative assessment [45]. Together, these parameters support more appropriate patient selection and more informed perioperative decision-making.

6.4 Surgical Parameters

Surgical parameters relevant to postoperative outcomes and cost include the technique employed (on-pump versus off-pump), number of grafts, total operative time, cardiopulmonary bypass time, and aortic cross-clamp time [46]. As the length and technical complexity of surgery increase, so too does the risk of complications and associated healthcare costs [47]. Evaluating these parameters alongside frailty status helps clarify how surgical complexity interacts with physiological vulnerability to shape postoperative recovery and resource use [48].

7. Health Economic Burden of CABG

Direct medical costs constitute a substantial proportion of the overall cost of CABG [49]. These costs begin before surgery, with diagnostic workup such as coronary angiography, and continue through the operative period, encompassing operating room time, specialized surgical equipment, cardiopulmonary bypass support, grafting materials, anesthesia, and professional fees [50]. Postoperative costs, including intensive care, ventilatory support, and nursing care, add further to the overall economic burden, and any prolongation of hospital stay increases total treatment costs accordingly [51].

Complications represent another major driver of the economic burden of CABG [52]. Infection, bleeding, stroke, arrhythmia, and renal failure each may necessitate additional investigations, treatment, and prolonged intensive care, extending the rehabilitation process. These complications occur disproportionately among frail and elderly patients, compounding the cost burden on healthcare systems [53].

Indirect costs also contribute meaningfully to the total economic burden of CABG [54]. These include lost productivity resulting from prolonged recovery, disability, or premature death, as well as the costs associated with rehabilitation, physical therapy, and ongoing follow-up [55]. Some patients are unable to return to their prior functional baseline, which can affect their capacity to work or live independently and may generate an ongoing need for supportive care [54].

Hospital readmissions further compound this economic burden. CABG patients may require readmission if complications arise or their clinical condition

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deteriorates, generating additional costs for both patients and the broader healthcare system [56].

8. Economic Evaluation Methodology and Evidence for Frailty Screening

Robust cost-effectiveness analysis in cardiac surgery typically relies on decision-analytic modeling, commonly decision-tree or Markov approaches, that synthesize costs and quality-adjusted life years (QALYs) over an appropriate time horizon, informed by best-practice methodological guidance [57]. Applying this framework, recent economic modeling has demonstrated that routine frailty assessment before CABG in older patients, incorporating instruments such as the RAI, can be a cost-effective strategy relative to usual care, generating favorable incremental cost-effectiveness ratios by preventing costly downstream complications and reducing unnecessary resource utilization [58].

These findings are consistent with the broader literature comparing revascularization strategies, which has generally found CABG to be an economically reasonable option relative to medical therapy and PCI in patients with complex disease, provided that perioperative risk is appropriately managed [59]. Established methodological standards for reporting and interpreting cost-effectiveness analyses, including appropriate characterization of uncertainty and transparent reporting of assumptions, remain essential to ensuring that such economic evaluations are valid and generalizable to real-world practice [60].

9. Conclusion

Frailty has emerged as a critical determinant of surgical outcome in older adults undergoing coronary artery bypass grafting. Incorporating frailty assessment into preoperative evaluation provides clinicians with a more complete understanding of a patient's physiological reserve, thereby improving risk stratification and supporting more informed, individualized treatment decisions. From a health-economic perspective, the available evidence indicates that frailty assessment not only improves clinical outcomes but is also a cost-effective addition to preoperative care pathways. Wider adoption of validated screening instruments, such as the Risk Analysis Index, may therefore enhance both the clinical and economic value of CABG in an increasingly older and more comorbid surgical population.

Refrences

1. Okrainec K, Banerjee DK, Eisenberg MJ. Coronary artery disease in the developing world. Am Heart J 2004;148:7–15. https://doi.org/10.1016/j.ahj.2003.11.027.
2. Alexander JH, Smith PK. Coronary-Artery Bypass Grafting. New England Journal of Medicine 2016;374:1954–64. https://doi.org/10.1056/NEJMra1406944.
3. Neumann F-J, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J 2019;40:87–165. https://doi.org/10.1093/eurheartj/ehy394.
4. Panagiotopoulos I, Leivaditis V, Sawafta A, Katinioti A, Tasios K, Garantzioti V, et al. The choice of conduits in coronary artery bypass surgery. Arch Med Sci Atheroscler Dis 2023;8:e83–8. https://doi.org/10.5114/amsad/170215.
5. Melly L, Torregrossa G, Lee T, Jansens J-L, Puskas JD. Fifty years of coronary artery bypass grafting. J Thorac Dis 2018;10:1960–7. https://doi.org/10.21037/jtd.2018.02.43.
6. Ghandakly EC, Iacona GM, Bakaeen FG. Coronary Artery Surgery: Past, Present, and Future. Rambam Maimonides Med J 2024;15:e0001. https://doi.org/10.5041/RMMJ.10515.
7. Farkouh ME, Domanski M, Sleeper LA, Siami FS, Dangas G, Mack M, et al. Strategies for Multivessel Revascularization in Patients with Diabetes. New England Journal of Medicine 2012;367:2375–84. https://doi.org/10.1056/NEJMoa1211585.
8. Ngo ALT, Tiojanco M, Miller I, Nguyen L, Nguyen UT, Duong C. Frailty as a Surgical Vital Sign: A Narrative Review of Risk Stratification and Outcomes in General Surgery. Cureus 2026. https://doi.org/10.7759/cureus.108188.
9. Kalladi R, Elavally S, Rojan PM, Usharani EN. Frailty: An overview. J Family Med Prim Care 2026;15:39–44. https://doi.org/10.4103/jfmpc.jfmpc_1748_25.
10. Chen S, Zhang S, Cai S, Wang H. Impact of frailty on outcomes following coronary artery bypass grafting: a systematic review and meta-analysis. BMC Surg 2024;24:419. https://doi.org/10.1186/s12893-024-02728-1.

11. O'Connor E, Browne G. Frailty assessment in the pre-operative setting. Anaesthesia & Intensive Care Medicine 2026;27:413–8. https://doi.org/10.1016/j.mpaic.2026.06.002.
12. Sung T-Y, Oh C-S. Frailty assessment in perioperative geriatric patients: a narrative review. Anesth Pain Med (Seoul) 2026;21:51–66. https://doi.org/10.17085/apm.25480.
13. Li Z, Habbous S, Thain J, Hall DE, Nagpal AD, Bagur R, et al. Cost-Effectiveness Analysis of Frailty Assessment in Older Patients Undergoing Coronary Artery Bypass Grafting Surgery. Can J Cardiol 2020;36:490–9. https://doi.org/10.1016/j.cjca.2019.09.025.
14. Thakare V s, Sontakke NG, Wasnik P, Kanyal D. Recent Advances in Coronary Artery Bypass Grafting Techniques and Outcomes: A Narrative Review. Cureus 2023. https://doi.org/10.7759/cureus.45511.
15. Aronson D, Edelman ER. Revascularization for coronary artery disease in diabetes mellitus: angioplasty, stents and coronary artery bypass grafting. Rev Endocr Metab Disord 2010;11:75–86. https://doi.org/10.1007/s11154-010-9135-3.
16. Hameed I, Talapaneni S, Fatimi AS, Bazarbaev A, Dankwa S, Candelario K, et al. Contemporary cardiac surgery outcomes databases: Data sources, variables, and applications. JTCVS Open 2026;29:101485. https://doi.org/10.1016/j.xjon.2025.10.011.
17. Lemaire A, Soto C, Salgueiro L, Ikegami H, Russo MJ, Lee LY. The impact of age on outcomes of coronary artery bypass grafting. J Cardiothorac Surg 2020;15:158. https://doi.org/10.1186/s13019-020-01201-3.
18. Nashef SAM, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). European Journal of Cardio-Thoracic Surgery 1999;16:9–13. https://doi.org/10.1016/S1010-7940(99)00134-7.
19. Guo Y, Hu Y, Chen R, Yang Y, Hu C, Yao H, et al. Frailty syndrome in older adults: Research advances and management strategies. IScience 2026;29:116264. https://doi.org/10.1016/j.isci.2026.116264.
20. Evans LK, Moffatt C, Niknejad K, Yang H, Kodaverdian L, Soliman S, et al. Risk Analysis Index Frailty Score as a Predictor of Otolaryngology Surgical Outcomes. Otolaryngology–Head and Neck Surgery 2024;171:1728–35. https://doi.org/10.1002/ohn.899.
21. Shen H, Ju M, Wu X, Shi S, Sun J, Tian M. The application value of frailty assessment tools in the perioperative period: A narrative review. Journal of Anesthesia and Translational Medicine 2026;5:90–103. https://doi.org/10.1016/j.jatmed.2026.04.002.
22. Sarmadi S, Sanaie N, Zare-Kaseb A. Prevalence and risk factors of frailty among cardiac surgery patients: a systematic review and meta-analysis. Ann Med 2025;57. https://doi.org/10.1080/07853890.2025.2576638.
23. Aprea G, Capuano M, Palomba G. The Impact of Aging Population on General Surgical Workforce Needs, 2024, p. 29–38. https://doi.org/10.1007/978-3-031-77707-3_3.
24. Wang L, Chao J, Zhang N, Li X, Li J, Jin S, et al. Prevalence and Factors Associated with Sarcopenia in Community-Dwelling Older Adults: A Systematic Review and Meta-Analysis. Gerontology 2025;72:110–25. https://doi.org/10.1159/000549808.
25. Santulli G, Sabatelli G, Wang B, Savino M, Bruno FP, Jankauskas SS, et al. Interplay between frailty and cardiometabolic disorders: from pathophysiology to clinical implications. Cardiovasc Diabetol 2025;25:1. https://doi.org/10.1186/s12933-025-03022-x.
26. Alotaibi F, Alshibani A, Banerjee J, Manktelow B. The association between frailty and hospital-related adverse events in older hospitalised patients: a systematic literature review. Eur Geriatr Med 2025;16:1303–18. https://doi.org/10.1007/s41999-025-01242-8.
27. Cullaro G, Verna EC, Duarte-Rojo A, Kappus MR, Ganger DR, Rahimi RS, et al. Frailty and the Risk of Acute Kidney Injury Among Patients With Cirrhosis. Hepatol Commun 2022;6:910–9. https://doi.org/10.1002/hep4.1840.
28. Lee JA, Yanagawa B, An KR, Arora RC, Verma S, Friedrich JO. Frailty and pre-frailty in cardiac surgery: a systematic review and meta-analysis of 66,448 patients. J Cardiothorac Surg 2021;16:184. https://doi.org/10.1186/s13019-021-01541-8.

29. Saxena S, Singhal S, Gurjar M, Kumar K, Mudgal SK. Impact of frailty on hospital and intensive care unit readmission among critically ill patients: A systematic review and meta-analysis. Medicina Intensiva (English Edition) 2026:502565. https://doi.org/10.1016/j.medine.2026.502565.
30. Ahrenfeldt LJ, Möller S, Thinggaard M, Christensen K, Lindahl-Jacobsen R. Sex Differences in Comorbidity and Frailty in Europe. Int J Public Health 2019;64:1025–36. https://doi.org/10.1007/s00038-019-01270-9.
31. Tan V, Chen C, Merchant RA. Association of social determinants of health with frailty, cognitive impairment, and self-rated health among older adults. PLoS One 2022;17:e0277290. https://doi.org/10.1371/journal.pone.0277290.
32. Chandiramani A, Ali JM. Frailty in Cardiac Surgery—Assessment Tools, Impact on Outcomes, and Optimisation Strategies: A Narrative Review. J Cardiovasc Dev Dis 2025;12:127. https://doi.org/10.3390/jcdd12040127.
33. Johnson A, Hore E, Milne B, Muscedere J, Peng Y, McIsaac DI, et al. A Frailty Index to Predict Mortality, Resource Utilization and Costs in Patients Undergoing Coronary Artery Bypass Graft Surgery in Ontario. CJC Open 2024;6:72–81. https://doi.org/10.1016/j.cjco.2023.10.010.
34. Żółkowska B, Lee CS, Denfeld QE, Jędrzejczyk M, Diakowska D, Lisiak M, et al. Clinical and Psychological Factors Associated with Frailty in Patients with Heart Failure. J Clin Med 2024;13:7345. https://doi.org/10.3390/jcm13237345.
35. Chatmongkolchart S, Saetang M, Kittisopaporn P, Kunapaisal T, Yongsata D, Sukitpaneenit K. Frailty and nutritional assessments for predicting postoperative complications in older adults undergoing non-cardiac surgery. Front Med (Lausanne) 2025;12. https://doi.org/10.3389/fmed.2025.1636091.
36. Jin Z, Rismany J, Gidicsin C, Bergese SD. Frailty: the perioperative and anesthesia challenges of an emerging pandemic. J Anesth 2023;37:624–40. https://doi.org/10.1007/s00540-023-03206-3.
37. Nilsson U, Amirpour A, Lampi M, Guenna Holmgren A, Markovic G, Zecevic E, et al. Older Patients' Postoperative Neurocognitive Recovery: A Narrative Review. Clin Interv Aging 2025;Volume 20:2579–91. https://doi.org/10.2147/CIA.S559531.
38. Pozzi M, Mariani S, Scanziani M, Passolunghi D, Bruni A, Finazzi A, et al. The frail patient undergoing cardiac surgery: lessons learned and future perspectives. Front Cardiovasc Med 2023;10. https://doi.org/10.3389/fcvm.2023.1295108.
39. Min JJ, Kaplan B, Ellison-Barnes A, Galiatsatos P. Associations of Smoking Behaviors and Body Mass Index Among American Participants of a Clinical Tobacco Cessation Program: A Pilot Study. Tob Use Insights 2024;17. https://doi.org/10.1177/1179173X241272359.
40. Doody P, Lord JM, Greig CA, Whittaker AC. Frailty: Pathophysiology, Theoretical and Operational Definition(s), Impact, Prevalence, Management and Prevention, in an Increasingly Economically Developed and Ageing World. Gerontology 2023;69:927–45. https://doi.org/10.1159/000528561.
41. Humphries KH, Izadnegahdar M, Sedlak T, Saw J, Johnston N, Schenck-Gustafsson K, et al. Sex differences in cardiovascular disease – Impact on care and outcomes. Front Neuroendocrinol 2017;46:46–70. https://doi.org/10.1016/j.yfrne.2017.04.001.
42. Endo D, Yamamoto T, Kajimoto K, Matsushita S, Dohi S, Shimada A, et al. Coronary Artery Bypass Grafting in Patients with Chronic Kidney Disease: Chronic Kidney Disease Has an Independent Adverse Effect on the Long-Term Outcome of Coronary Artery Bypass Grafting. Biomed Res Int 2022;2022. https://doi.org/10.1155/2022/4994970.
43. RAPTIS DA, HANNA T, MACHAIRAS N, OWEN T, DAVIES D, FUSAI GK. The Economic Burden of Postoperative Complications Predicted by the Comprehensive Complication Index ® in Patients Undergoing Elective Major Hepatopancreaticobiliary Surgery for Malignancy – A Prospective Cost Analysis. In Vivo (Brooklyn) 2021;35:1065–71. https://doi.org/10.21873/invivo.12351.
44. Nidadavolu LS, Ehrlich AL, Sieber FE, Oh ES. Preoperative Evaluation of the Frail Patient. Anesth Analg 2020;130:1493–503. https://doi.org/10.1213/ANE.0000000000004735.
45. Pashmdarfard M, Azad A. Assessment tools to evaluate Activities of Daily Living (ADL) and

Instrumental Activities of Daily Living (IADL) in older adults: A systematic review. Med J Islam Repub Iran 2020;34:33. https://doi.org/10.34171/mjiri.34.33.

46. He L, Tiemuerniyazi X, Chen L, Yang Z, Huang S, Nan Y, et al. Clinical outcomes of on-pump versus off-pump coronary-artery bypass surgery: a meta-analysis. International Journal of Surgery 2024;110:5063–70. https://doi.org/10.1097/JS9.0000000000001481.
47. Hedou J, Mendes G, Bellan G, El Khoury D, Verdonk F. Impact of postoperative complications on cost and length of stay: multicentre prospective clinical study. British Journal of Surgery 2025;113. https://doi.org/10.1093/bjs/znaf290.
48. Han B, Li Q, Chen X. Effects of the frailty phenotype on post-operative complications in older surgical patients: a systematic review and meta-analysis. BMC Geriatr 2019;19:141. https://doi.org/10.1186/s12877-019-1153-8.
49. Darba S, Safaei N, Mahboub–Ahari A, Nosratnejad S, Alizadeh G, Ameri H, et al. <p>Direct and Indirect Costs Associated with Coronary Artery (Heart) Disease in Tabriz, Iran</p>. Risk Manag Healthc Policy 2020;Volume 13:969–78. https://doi.org/10.2147/RMHP.S261612.
50. Chung W, Fan P, Chiu H, Yang C, Huang K, Tzeng D. Operating room cost for coronary artery bypass graft procedures: does experience or severity of illness matter? J Eval Clin Pract 2010;16:1063–70. https://doi.org/10.1111/j.1365-2753.2009.01251.x.
51. Kaier K, Heister T, Motschall E, Hehn P, Bluhmki T, Wolkewitz M. Impact of mechanical ventilation on the daily costs of ICU care: a systematic review and meta regression. Epidemiol Infect 2019;147:e314. https://doi.org/10.1017/S0950268819001900.
52. Mehaffey JH, Hawkins RB, Byler M, Charles EJ, Fonner C, Kron I, et al. Cost of individual complications following coronary artery bypass grafting. J Thorac Cardiovasc Surg 2018;155:875-882.e1. https://doi.org/10.1016/j.jtcvs.2017.08.144.
53. Nowak W, Kowalik I, Nowicki M, Cichocki T, Stępińska J. The impact of frailty on in-hospital complications in elderly patients with acute coronary syndrome. Journal of Geriatric Cardiology 2023;20:174–84. https://doi.org/10.26599/1671-5411.2023.03.003.
54. Narayan I, Chopra RC, Sarkar S, Chakrabarthi S. Financial burden of coronary artery bypass grafting in India: implications for catastrophic health expenditure and healthcare access. Indian J Thorac Cardiovasc Surg 2024;40:78–82. https://doi.org/10.1007/s12055-023-01612-6.
55. Hanly P, Ahern M, Sharp L, Ursul D, Loughnane G. The cost of lost productivity due to premature mortality associated with COVID-19: a Pan-European study. The European Journal of Health Economics 2022;23:249–59. https://doi.org/10.1007/s10198-021-01351-8.
56. Shawon MSR, Odutola M, Falster MO, Jorm LR. Patient and hospital factors associated with 30-day readmissions after coronary artery bypass graft (CABG) surgery: a systematic review and meta-analysis. J Cardiothorac Surg 2021;16:172. https://doi.org/10.1186/s13019-021-01556-1.
57. Vervoort D, Lee GS, Lia H, Afzal AM, Tam DY, Ouzounian M, et al. Decision analysis in cardiac surgery: a scoping review and methodological primer. European Journal of Cardio-Thoracic Surgery 2024;65. https://doi.org/10.1093/ejcts/ezae123.
58. Dicpinigaitis AJ, Khamzina Y, Hall DE, Nassereldine H, Kennedy J, Seymour CW, et al. Adaptation of the Risk Analysis Index for Frailty Assessment Using Diagnostic Codes. JAMA Netw Open 2024;7:e2413166. https://doi.org/10.1001/jamanetworkopen.2024.13166.
59. Faradonbeh SB, Ebadi Fard Azar F, Rezapour A, Hajahmadi M, Hajmiresmail SJ. Comparing the effectiveness of revascularization interventions with medical therapy in patients with ischemic cardiomyopathy: A systematic review and meta-analysis. Med J Islam Repub Iran 2018:743–53. https://doi.org/10.14196/mjiri.32.127.
60. Krebs E, Nosyk B. Cost-Effectiveness Analysis in Implementation Science: a Research Agenda and Call for Wider Application. Curr HIV/AIDS Rep 2021;18:176–85. https://doi.org/10.1007/s11904-021-00550-5.