Bui R, Dong JL, Tran A, et al. Navigating Severe Aortic Stenosis in Hip Fracture Surgery: Perioperative Management and Surgical Timing. *Orthopedic Reviews*. 2026;18. doi:10.52965/001c.173791

General

Navigating Severe Aortic Stenosis in Hip Fracture Surgery: Perioperative Management and Surgical Timing

Richard Bui[1], Jen Li Dong[1], Austin Tran[1], Laasya Achanta[1], Jamal Hasoon[2], Alaa Abd-Elsayed[3], Alan D Kaye[4], Anvinh Nguyen[1]

[1] Department of Anesthesiology, Baylor College of Medicine, [2] Department of Anesthesiology, Critical Care, and Pain Medicine, The University of Texas Health Science Center at Houston, [3] Department of Anesthesiology, University of Wisconsin School of Medicine and Public Health, [4] Department of Anesthesiology, Louisiana State University Health Sciences Center Shreveport

Keywords: aortic stenosis, hip fracture, anesthesiology, orthopedic surgery

https://doi.org/10.52965/001c.173791

Orthopedic Reviews

Vol. 18, 2026

Severe aortic stenosis presents a significant challenge in patients requiring urgent hip fracture surgery. Although aortic stenosis increases the risk of cardiovascular complications and mortality, delaying fixation may independently contribute to morbidity, functional decline, and mortality. This creates a dilemma regarding whether to proceed directly to surgery or delay fracture repair for aortic valve intervention. This review examines management of patients with severe aortic stenosis pending urgent hip fracture surgery, with emphasis on timing, preoperative evaluation, anesthetic selection, and hemodynamic management. Current evidence suggests that asymptomatic patients with preserved left ventricular systolic function and stable hemodynamics may often undergo timely fracture fixation with appropriate monitoring. In contrast, symptomatic patients, those with ventricular dysfunction or hemodynamic instability, and patients with particularly severe disease may require evaluation for valvular intervention. When intervention is indicated, transcatheter aortic valve replacement may offer a more rapid treatment in certain patients, while balloon aortic valvuloplasty may serve as a temporizing strategy. For patients proceeding directly to fracture fixation, preservation of preload, systemic vascular resistance, coronary perfusion, and sinus rhythm is essential. Current evidence does not establish a clear superiority of general versus neuraxial anesthesia, supporting individualized anesthetic planning and avoidance of abrupt hemodynamic changes. Ultimately, management should balance the risks of delaying fracture fixation against the risks of surgery through coordinated, multidisciplinary decision-making.

INTRODUCTION

Hip fractures are among the most consequential acute injuries in older adults, carrying substantial risks of mortality, functional decline, and medical complications. Timely operative fixation is a central component of management, with increasing evidence supporting surgery within 24-48 hours of presentation when medically feasible. Delaying surgery for extensive medical optimization may itself contribute to adverse outcomes, creating a narrow window in which competing medical conditions must be evaluated without unnecessarily postponing fracture repair.[1,2] This challenge is particularly relevant in the growing population of older adults with severe aortic stenosis, a condition increasingly encountered during preoperative evaluation for urgent non-cardiac surgery.

Severe aortic stenosis presents a unique perioperative challenge because the fixed left ventricular outflow obstruction limits the cardiovascular system's ability to compensate for changes in preload, afterload, heart rate, and contractility. Severe aortic stenosis is independently associated with increased perioperative cardiovascular events and mortality, with substantially greater risk among patients who are symptomatic or have impaired ventricular function.[1,2] Consequently, the discovery of severe aortic stenosis in a patient presenting with an acute hip fracture raises a fundamental clinical dilemma: should fracture fixation proceed promptly, or should surgery be delayed allowing for aortic valve intervention? Neither approach is universally appropriate. Rather, the optimal strategy depends on the urgency of fracture repair, aortic stenosis severity and symptom status, left ventricular function, overall hemodynamic stability, and the feasibility and timing of definitive valve intervention.[2]

Symptom status is particularly important in determining the need for preoperative valve intervention. Current guidelines generally recommend valve replacement before elective non-cardiac surgery in patients with symptomatic severe aortic stenosis who meet criteria for intervention, whereas asymptomatic patients with preserved left ventricular systolic function may undergo necessary non-car-

diac surgery with appropriate perioperative monitoring and hemodynamic management.[1,3] However, determining whether an older adult with a hip fracture is truly asymptomatic can be difficult because acute pain, immobility, and limited functional capacity may obscure exertional dyspnea, angina, or syncope. Furthermore, assessment of aortic stenosis severity must account for low-flow, low-gradient disease and associated abnormalities in ventricular function and pulmonary pressures.[2,3]

When valve intervention is indicated, the feasibility and timing of treatment further complicate decision-making. Surgical valve replacement may introduce substantial delays in fracture fixation, whereas transcatheter aortic valve replacement (TAVR) can provide a more rapid treatment pathway for appropriately selected patients. Balloon aortic valvuloplasty (BAV) may also serve as a temporizing strategy when urgent surgery cannot safely be postponed, although evidence regarding its benefit remains mixed.[2,4] Emerging time-sensitive pathways have therefore emphasized multidisciplinary assessment and, when appropriate, expedited TAVR followed by hip fracture repair during the same hospitalization.[1,2]

For patients who proceed directly to fracture fixation without prior valve intervention, anesthetic management becomes an important component of risk mitigation. The hemodynamic consequences of severe aortic stenosis necessitate preservation of preload, systemic vascular resistance, sinus rhythm, and an appropriately controlled heart rate, while avoiding hypotension, tachycardia, hypovolemia, and excessive volume administration.[2,3] The choice between general, neuraxial, and regional anesthetic techniques must therefore be individualized according to the severity of valvular disease, patient comorbidities, procedural requirements, and institutional expertise. Enhanced monitoring, including invasive arterial pressure monitoring and selected use of advanced hemodynamic monitoring or transesophageal echocardiography (TEE), may be warranted in patients at particularly high risk.[2,3]

This narrative review examines the contemporary approach to severe aortic stenosis in patients requiring urgent hip fracture surgery. Emphasis is placed on the competing risks of delaying fracture fixation for valve intervention versus going directly to surgery, the clinical factors that should guide this decision, the relative considerations of general and neuraxial anesthesia, and perioperative strategies for maintaining hemodynamic stability. The goal is to provide a practical framework for individualized, multidisciplinary decision-making in this increasingly common and high-risk clinical scenario.

METHODS

This narrative review was developed through a focused literature search of PubMed/MEDLINE for English-language publications addressing the perioperative management of patients with severe aortic stenosis undergoing hip fracture surgery and other noncardiac procedures. Search terms included combinations of "aortic stenosis," "hip fracture," "noncardiac surgery," "perioperative management," "surgical timing," "aortic valve replacement," "balloon aortic valvuloplasty," "general anesthesia," "neuraxial anesthesia," and "hemodynamic monitoring." Relevant clinical guidelines and references from selected publications were also reviewed. Priority was given to clinical guidelines, systematic reviews, randomized controlled trials, and observational studies directly relevant to perioperative decision-making. Since the objective was to provide a clinically oriented narrative synthesis rather than an exhaustive systematic review, study selection was purposive, and no formal risk-of-bias assessment or meta-analysis was performed. Findings were organized thematically to evaluate surgical timing, preoperative risk assessment, indications for valvular intervention, anesthetic selection, intraoperative management, and postoperative recovery.

HIP FRACTURE SURGERY: WHY TIMING MATTERS

Hip fractures are common in older adults and are associated with substantial mortality, functional decline, and healthcare costs. In 2019, an estimated 9.6 million hip fractures occurred worldwide among adults aged 55 years and older, with a global incidence of 681 cases per 100,000 people.[5] Although outcomes have improved over time, mortality after hip fracture remains high. Across six decades, mean one-year mortality decreased from 27% in the 1960s to 20% in the 2010s, with more recent estimates ranging from 15% to 30%.[5,6] Many patients who survive also experience lasting declines in their ability to function independently. In a longitudinal study of 726 older adults, none of the identified patient groups returned to their pre-fracture level of activities of daily living within 12 months, with little additional improvement between four and 12 months after surgery.[7] The financial burden is also substantial. An analysis of the United States National Inpatient Sample estimated $30.5 billion in inpatient costs from hip fracture hospitalizations among adults aged 65 years and older between 2016 and 2020.[8] Altogether, hip fractures remain a major source of mortality, loss of independence, and healthcare utilization in the growing older adult population.

Early surgical repair is generally preferred after hip fracture, although the relationship between surgical timing and mortality is not straightforward. In a cohort of 1,803 patients that excluded those whose surgery was postponed for medical reasons, waiting more than 24 hours was not associated with higher 30-day mortality.[9] Similarly, a prospective study found no difference in one-year mortality when comparing surgery before and after 48 hours. However, when delay was considered as a continuous measure rather than using a 48-hour cutoff, mortality increased as time to surgery increased, particularly in patients who were not medically fit for surgery.[10] This relationship may be more apparent with prolonged delays. One study reported one-year mortality of 21% in patients undergoing surgery within 12 days compared with 39% in those waiting longer than 12 days.[11] These findings suggest that the impact of surgical

delay on mortality may depend on both how long surgery is postponed and why the delay occurs.

Beyond mortality, hip fracture patients are vulnerable to several perioperative complications, some of which may become more likely with surgical delay. Postoperative pneumonia occurs in approximately 10% to 13% of older patients undergoing surgery for hip or femoral fractures and has been associated with increased intensive care unit (ICU) utilization and longer hospitalization.[12,13] A meta-analysis of 10 studies including 12,084 older patients found that delayed hip fracture surgery was associated with greater odds of postoperative pneumonia (odds ratio [OR] 6.40, 95% confidence interval [CI] 3.00-13.68).[14] Venous thromboembolism is another complication associated with surgical delay. Among 862 patients aged 65 years and older, surgery more than 48 hours after hip fracture was independently associated with increased risk of postoperative venous thromboembolism and proximal deep vein thrombosis.[15] Delirium is also a significant source of morbidity in this population. In a cohort of 2,051 patients older than 70 years, 16% developed delirium following hip fracture surgery. These patients had a longer median hospital stay (9 vs. 6 days) and higher 30-day mortality (16% vs. 6%).[16] Anticoagulant and antiplatelet therapy can further complicate surgical timing, and delays beyond 48 hours in these patients have been associated with twice the odds of postoperative complications.[17] Longer time to surgery may also extend hospitalization. In one study, patients undergoing surgery after 48 hours remained hospitalized four days longer than those treated earlier, and each additional 10-hour delay beyond 48 hours was associated with another 7.3 hours of hospitalization.[18] A larger analysis of 17,459 patients similarly found longer postoperative hospital stays as time to surgery increased, despite no significant worsening of 30-day postoperative outcomes.[19]

Despite some variability across individual studies, the overall evidence favors timely hip fracture repair, with 24 to 48 hours commonly used as the target window. A meta-analysis of 35 studies including 191,873 patients found that early surgery, most often defined using a 24- to 48-hour cutoff, was associated with lower mortality (OR 0.74, 95% CI 0.67-0.81) and fewer pressure sores (OR 0.48, 95% CI 0.38–0.60).[20] More recent studies have generally supported avoiding unnecessary delays. In a prospective cohort of 10,659 patients, waiting more than 12 hours after admission was associated with higher 30-day mortality compared with surgery within 12 hours, although this difference was not seen at the other timing thresholds examined.[21] Delays beyond 48 hours have also been associated with higher mortality, more postoperative complications, and longer hospitalization, while adoption of a 48-hour surgical target has been associated with fewer complications and shorter hospital stays.[22-25] However, patients who experience surgical delays also tend to be medically more complex, with higher rates of heart failure, bleeding disorders, anticoagulant use, and higher aortic stenosis classification, making it difficult to separate the effects of waiting from the conditions that prompted the delay.[26] Studies accounting for active medical problems have found no significant relationship between surgical timing and short- or long-term mortality, and other data suggest that using the first 24 to 48 hours for medical optimization may benefit higher-risk patients.[22,27] Therefore, hip fracture repair within 24 to 48 hours remains a reasonable goal for most patients, while allowing time for necessary medical optimization when proceeding immediately may introduce greater perioperative risk.

SEVERE AORTIC STENOSIS

The prevalence of aortic stenosis increases substantially with age, creating considerable overlap with the older population at the greatest risk for hip fracture. Calcific aortic valve disease is the most common cause of aortic stenosis in adults and becomes increasingly prevalent in older age.[28] Aortic stenosis affects approximately 1.7% of adults older than 65 years and 3.4% of those older than 75 years.[28] Among older adults presenting with hip fracture, severe aortic stenosis is estimated to occur in approximately 5% of patients.[29] In one cohort of patients with severe aortic stenosis undergoing hip fracture surgery, in-hospital mortality was 10.4%, with greater comorbidity burden and elevated pulmonary artery (PA) pressure independently associated with mortality.[29] Given the overlap between these conditions, severe aortic stenosis represents an important source of perioperative risk when determining how to safely proceed with timely hip fracture repair.

Calcific aortic stenosis develops as progressive thickening and calcification of the aortic valve leaflets restrict valve opening and obstruct left ventricular outflow.[30] As the degree of stenosis worsens, the left ventricle must generate progressively greater pressure to eject blood across the narrowed valve. The ventricle initially adapts to this chronic pressure load through concentric hypertrophy, which reduces wall stress and helps preserve systolic function.[30,31] Over time, however, this compensatory response becomes less effective. Continued pressure overload and myocardial fibrosis increase ventricular stiffness, impair relaxation, and contribute to diastolic dysfunction. With more advanced disease, contractile reserve may also decline and eventually lead to systolic dysfunction.[31] The overall hemodynamic burden can be further increased by arterial stiffness and systemic vascular load, adding to the afterload already imposed by the stenotic valve.[32]

Coronary perfusion can also become impaired as aortic stenosis progresses. Left ventricular hypertrophy increases myocardial oxygen demand, while elevated ventricular pressures and changes in the coronary microvasculature can limit myocardial oxygen supply.[31] Capillary growth may not adequately match the increase in myocardial mass, contributing to reduced coronary reserve and impaired subendocardial perfusion.[31] Arterial stiffness can further increase systolic load while reductions in diastolic pressure compromise coronary perfusion.[32] The resulting imbalance between myocardial oxygen supply and demand increases susceptibility to ischemia.[31] Together, progressive outflow obstruction, ventricular remodeling, diastolic dysfunction, and reduced coronary reserve make patients with severe

aortic stenosis particularly vulnerable to acute hemodynamic changes during the perioperative period.

These physiologic changes guide the major hemodynamic goals for patients with severe aortic stenosis undergoing non-cardiac surgery. Adequate preload should be maintained to support ventricular filling, while abrupt reductions in afterload should be avoided to preserve systemic and coronary perfusion.[33] Maintaining sinus rhythm is also important, particularly in patients with a stiff, hypertrophied ventricle and impaired diastolic filling.[31,33] Tachycardia should be avoided because shortening of diastole reduces ventricular filling time and may further worsen the imbalance between myocardial oxygen supply and demand. Maintaining hemodynamic stability throughout anesthesia and surgery is therefore particularly important, as sudden changes in vascular tone, ventricular filling, or cardiac rhythm may be poorly tolerated in patients with severe aortic stenosis.[33]

PREOPERATIVE EVALUATION

Patients with severe aortic stenosis presenting with acute hip fractures represent a particularly challenging perioperative population. The hemodynamic consequences of severe valvular obstruction, particularly under general anesthesia and surgical stress, must be carefully weighed against the time-sensitive nature of hip fracture repair. Severe aortic stenosis is associated with higher 30-day perioperative complications, 30-day mortality, 1-year mortality, and postoperative non-fatal myocardial infarction in patients undergoing hip fracture surgery.[34-36] Delays in hip fracture fixation are themselves associated with adverse outcomes. A meta-analysis by Klestil et al. found that hip surgery within 48 hours had a 20% lower risk of mortality within 12 months.[37] Accordingly, the preoperative evaluation should extend beyond echocardiographic assessment of aortic stenosis severity to include symptom status, ventricular function, hemodynamic stability, functional status, and relevant comorbidities, all of which influence the safety and timing of fracture fixation.

CLINICAL ASSESSMENT

The initial clinical evaluation should establish whether aortic stenosis is clinically symptomatic and identify other relevant comorbidities. The most common symptoms associated with severe aortic stenosis include exertional dyspnea, angina, presyncope, syncope, and ultimately, heart failure symptoms.[3,38] One large multicenter study of 330,940 individuals undergoing echocardiographic evaluation demonstrated that dyspnea was more prevalent among patients with severe compared with moderate aortic stenosis, supporting its value as a clinical marker of more advanced disease.[38] The presence of symptoms is important because symptomatic severe aortic stenosis carries worse prognosis than asymptomatic disease and is a determinant of whether aortic valve intervention should be considered before non-cardiac surgery.[2,39]

However, the assessment of symptom status in older patients presenting with acute hip fractures can be particularly challenging. Acute pain, immobility, frailty, and limited functional capacity may obscure the typical clinical manifestations of aortic stenosis. A careful effort should be made to establish pre-fracture functional status, with focus on the presence of exertional dyspnea, chest pain, presyncope, syncope, and heart failure symptoms. If a patient is unable to provide reliable history because of acute pain, delirium, dementia, or other cognitive impairment, collateral information from family members or caregivers may be valuable.

Frailty and functional status should also be incorporated into the preoperative risk assessment. With constantly evolving definitions, frailty largely centers around the decline in function and physiological reserves across multiple domains: mobility, strength, balance, motor processing, cognition, nutrition, endurance, and physical activity.[40] Furthermore, it has been increasingly recognized that frailty and cardiovascular disease have a bidirectional relationship and overlapping biological drivers including chronic inflammation, mitochondrial dysfunction, endothelial dysfunction, and hormonal dysregulation.[40,41] Thus, frailty, which is common in older adults with hip fractures, may reflect diminished physiological reserve, increasing vulnerability to the hemodynamic stress associated with anesthesia and hip surgery. At the same time, the clinician should recognize that frailty and functional status can also be attributed to comorbidities such as disability, deconditioning, and pulmonary disease, among others.

The comorbidities associated with aortic stenosis should also be thoroughly evaluated in the preoperative risk stratification. Diagnoses such as hypertension, coronary disease, and atrial fibrillation are more prevalent in symptomatic compared to asymptomatic patients ($p<0.001$).[38] In a cohort study of 66 patients with severe aortic stenosis undergoing hip fracture surgery, diabetes, heart failure, coronary artery disease, atrial fibrillation, pulmonary hypertension, and two or more comorbidities were associated with higher mortality.[36] These findings emphasize that preoperative risk associated with severe aortic stenosis is not only influenced by the valve lesion itself, but also by the extent of associated comorbidities.

ECHOCARDIOGRAPHY

Transthoracic echocardiography (TTE) is central and considered the standard for preoperative assessment of patients with known or suspected severe aortic stenosis. The 2024 American Heart Association/American College of Cardiology (AHA/ACC) guidelines recommend preoperative TTE, at least within 1 year, in patients with severe aortic stenosis undergoing elevated risk non-cardiac surgery to guide perioperative management.[2] The European Society of Cardiology/European Association for Cardio-Thoracic Surgery (ESC/EACTS) and the AHA/ACC have defined severe aortic stenosis as aortic jet velocity > 4.0 m/s, aortic valve area <1.0 cm^2 , or mean pressure gradient > 40 mm Hg.[2,39] Aortic jet velocity (or Vmax) measures the speed of blood as it flows through the aortic valve. The aortic valve area

measures the physical size of the opening when the valve is fully open. Lastly, the mean pressure gradient measures the average pressure difference across the valve. However, these parameters should not be interpreted in isolation, particularly in patients with discordant results.

There exists a subset of patients with aortic valve areas less than 1.0 cm^2, but with low-flows and low-gradients that do not meet the cutoff for severe aortic stenosis. For these patients, ESC/EACTS guidelines recommend considering other parameters like left ventricular ejection fraction (LVEF), left ventricular hypertrophy, and degree of valve calcification.[8] For low-flow, low-gradient aortic stenosis with reduced LVEF, low-dose dobutamine stress echocardiography is recommended to identify true severe aortic stenosis. For low-flow, low-gradient aortic stenosis with preserved LVEF, further evaluation of other valvular disease, clinical symptoms, left ventricular hypertrophy, and computed tomography with calcium scoring may be considered.[39] The prognostic importance of these parameters has also been demonstrated specifically in patients undergoing orthopedic hip fracture surgery. In a retrospective study by Cronin et al. comparing hip fracture patients with severe aortic stenosis vs. non-severe aortic stenosis, only aortic valve area and LVEF were associated with mortality ($p=0.015$ and $p<0.001$, respectively).[34] No significant effect was seen for aortic jet velocity, mean pressure gradient, peak pressure gradient.[34] These findings suggest that ventricular function, while not a key parameter in the diagnosis of severe aortic stenosis, may still serve as an important parameter in preoperative risk stratification. Overall, this is in alignment with AHA/ACC guidelines, which emphasize the importance of considering factors like coronary artery disease, valvular pathologies, left- and right-ventricular function, and PA pressure in perioperative planning.[2]

Although TTE provides crucial information to the clinician, its use must be also balanced against the time-sensitive nature of hip fracture surgery. One multi-institutional retrospective study compared the postoperative outcomes of hip fracture patients who underwent preoperative echocardiography for clearance and those who did not over a three-year period.[42] The study found statistically significant higher mean time to surgery (39.7 vs. 31.1 hours), length of hospital stays (6.7 vs. 5.3 days), postoperative complications, and 1-year mortality rate in the group who received preoperative echocardiogram. It is important to note that the cohort who received preoperative echocardiograms may have had higher baseline comorbidities. Overall, these findings do not suggest that preoperative echocardiography should be avoided. Rather, the study supports a selective approach to preoperative echocardiography.[42]

Thus, repeating echocardiography in a patient with a recent, high-quality echocardiography demonstrating stable valvular disease and preserved ventricular function may provide limited additional information. The goal should be to obtain the necessary information to characterize cardiovascular risk and guide clinical decision making without allowing preoperative diagnostic evaluation to become a source of avoidable delay in time-to-surgery. This is in alignment with current AHA/ACC guidelines which recommend that patients with suspected moderate or severe aortic stenosis should obtain repeat preoperative TTE if they have not had one within the past 12 months before non-cardiac surgery to aid in decision making.[2]

CURRENT GUIDELINES FOR PREOPERATIVE VALVULAR INTERVENTION

The current guidelines emphasize that the decision to pursue aortic valve intervention before non-cardiac surgery should be based on the patient's clinical presentation, standard indications for valve intervention, and urgency of non-cardiac surgery, rather than presence of severe aortic stenosis alone. The 2024 AHA/ACC guidelines recommend that patients with symptomatic severe aortic stenosis should undergo evaluation for transcatheter or surgical aortic valve replacement before *elective* elevated risk non-cardiac surgery. For those who are not candidates for valve replacement and require *urgent* non-cardiac surgery, such as hip fracture surgery, balloon aortic valvuloplasty may be considered as a bridging strategy. Asymptomatic patients with severe aortic stenosis and LVEF greater than 50% may proceed with *elective* low risk non-cardiac surgery. Asymptomatic severe aortic stenosis patients with LVEF less than 50% should be evaluated for aortic valve replacement candidacy before *elective* non-cardiac surgery. For patients with asymptomatic severe aortic stenosis with LVEF less than 50% undergoing *urgent* elevated risk non-cardiac surgery, such as hip fracture surgery, the guidelines emphasize a team-based approach to decide on the next steps.[2]

The 2025 ESC/EACTS guidelines similarly recommend management of severe aortic stenosis before non-cardiac surgery be individualized based on symptom status, surgical risk, and urgency of the non-cardiac surgery. In symptomatic patients with severe aortic stenosis who require *urgent* non-cardiac surgery, such as hip fracture surgery, surgery should be performed under strict hemodynamic monitoring. In other words, urgent surgery does not automatically require valve intervention first. Management of *elective* non-cardiac surgery is dependent on the presence of symptoms. In symptomatic severe aortic stenosis patients who are at high risk for aortic valve replacement, the ESC/EACTS recommends proceeding with *elective* surgery under strict monitoring and consideration of balloon aortic valvuloplasty in select populations. Symptomatic aortic stenosis patients who are at low risk for valve replacement should undergo evaluation before *elective* non-cardiac surgery. Similarly, for asymptomatic aortic stenosis patients undergoing high-risk elective non-cardiac surgery and who are at low risk for valve replacement, the guidelines recommend considering replacement. Asymptomatic aortic stenosis patients undergoing low-moderate risk non-cardiac surgery, such as hip fracture surgery, should proceed directly to non-cardiac surgery. In asymptomatic aortic stenosis patients who are at high risk for valve replacement, high-risk non-cardiac surgery can proceed under strict hemodynamic monitoring.[39] In this regard, standard American Society of Anesthesiologists monitoring should be employed in these patients, e.g. temperature, blood pressure, 5 lead EKG, capnography, and pulse oxime-

try. Additionally, a continuous arterial line to monitor beat-to-beat blood pressure, central venous catheter to provide vasoactive medications as needed, bispectral index monitoring, quantitative neuromuscular monitoring, and TEE, which can provide real time left ventricular filling, contractility, and assess wall motion should be utilized. Although the routine use of pulmonary artery catheters has declined in recent years, they remain valuable in select patients by providing detailed hemodynamic measurements, including pulmonary capillary wedge pressure and cardiac output. These measurements can be particularly useful in guiding management decisions in patients with complex or severe heart failure.

In summary, both guidelines support a multidisciplinary approach to determining the need for valvular intervention prior to non-cardiac surgery, with special consideration of patient symptoms, surgical urgency, and surgical risk. Both recognize that in severe aortic stenosis patients who require *urgent* non-cardiac surgery that cannot be delayed, such as hip fracture surgery, it may be reasonable to proceed directly with surgery under strict hemodynamic monitoring. In patients undergoing *elective* non-cardiac surgery where surgery can be potentially delayed and when standard indications for valve replacement are present, patients should be evaluated for such prior to surgery.[2,39]

PROCEED TO SURGERY OR DELAY?

In patients with severe aortic stenosis and hip fractures, the decision to proceed with or delay the surgery depends on the urgency of the orthopedic procedure, hemodynamic status, and existing cardiac symptoms.

The timing of non-cardiac procedures for this population is divided into four categories: emergency surgery for life or limb threatening event that requires immediate intervention (typically <2 hours), urgent surgery for life or limb threatening event that allows for critical pre-operative evaluation (⩾2 hours to <24 hours), time-sensitive surgery for cases that can be delayed up to 3 months without negative impacts, and elective surgery for cases that can be postponed for patient management and optimization.[2]

Hip fracture is generally classified as urgent non-cardiac surgery, with better outcomes if performed within 24-48 hours after admission and significant morbidity and mortality when delayed.[29,37] However, the increased operative risk of aortic stenosis creates tension for clinical decisions.[2] Clinicians must carefully balance the risk of proceeding with hip fracture fixation in patients with aortic stenosis and the risk of delaying it.

Early hip fracture fixation has been shown to decrease short- and long-term mortality.[37,43] A meta-analysis of 28 prospective observational studies indicates a 20% relative reduction in 12-month mortality for patients operated within 48 hours (risk ratio (RR) 0.80, 95% CI 0.66-0.97).[37] Another meta-analysis of 15 studies showed even better outcomes when surgery is carried out within 24 hours, with a RR of 0.86 (95% CI 0.82-0.91) for 30 days mortality in patients operated ⩽24 hours compared to patients operated >24 hours.[43]

Aortic stenosis in patients having non-cardiac surgery is associated with significant increase in mortality ($p<0.001$) and post-operative complications compared to patients without aortic stenosis.[44] Specifically, severe aortic stenosis significantly increases 30-day and 1-year mortality in patients following hip fracture surgery ($p<0.001$).[35,45] Hence, recent guidelines have demonstrated the need for a multidisciplinary assessment for aortic stenosis individuals undergoing hip fracture fixation based on the presence of their symptoms, hemodynamic stability, other comorbidities and availability of cardiac management resources.[2,46]

Patients who may proceed directly to urgent non-cardiac surgery generally have the following features: no evidence of aortic stenosis symptoms, such as angina, syncope, or dyspnea on exertion, preserved LVEF ⩾50%, absence of extreme valvular severity, hemodynamic stability, and no active or poorly controlled comorbid condition requiring stabilization, such as decompensated heart failure, active myocardial ischemia, significant pulmonary hypertension with right ventricular dysfunction, or uncontrolled atrial fibrillation.[1,2] Aortic stenosis severity, left ventricular function, and pulmonary pressure should also be reviewed upon admission with pre-operative TTE and point-of-care ultrasound.[2] Moreover, patients with aortic stenosis and preserved LVEF also require a comprehensive risk assessment to evaluate volume status and to identify and assess other comorbidities that can worsen outcomes such as significant pulmonary hypertension, coronary artery disease, diabetes, atrial fibrillation, and renal dysfunction.[29,47] For these patients, hip fracture fixation should be performed in a timely manner under invasive monitoring of hemodynamics and cardiac functions.[2,46] In contrast, elective surgery generally allows time for valve intervention when standard indications are present, without the same urgency associated with hip fracture fixation.[44,47]

Qualified patients with aortic stenosis who remain asymptomatic and clinically compensated can directly proceed with urgent hip fracture fixation under close monitoring and appropriate peri-operative optimization. Invasive monitoring with arterial lines with consideration of PA catheter or intraoperative TEE can lead to improved outcome.[2,45] Correctable problems such as electrolyte and metabolic abnormalities, inadequate volume status, anemia, medications, and treatable arrhythmias should be addressed promptly before surgery without any interference with time to surgery.[37]

Expedited multidisciplinary assessment for possible delay and valve intervention is warranted in patients with symptomatic aortic stenosis, reduced LVEF, extreme valvular severity, hemodynamic instability, and clinical decompensation.[2] According to the ESC/EACTS and AHA/ACC guidelines, the presence of LVEF < 50% in aortic stenosis patients warrants evaluation for cardiac intervention, for example valve replacement, regardless of symptoms.[47,48] The review by Herrera et al. supports aortic valve intervention prior to non-cardiac surgery in symptomatic aortic stenosis patients, showing improvement in overall survival and lower rates of postoperative cardiac complications.[46] However, we must keep in mind that hip fracture fixation is

Table 1. Management pathways for severe aortic stenosis in urgent hip fracture surgery

Clinical profile	Timing and management	Key considerations
Asymptomatic, clinically compensated; LVEF ≥50%; stable hemodynamics; no active condition requiring stabilization	Proceed with timely fracture fixation, generally within 24–48 hours when medically feasible.	Use close hemodynamic monitoring, usually including an arterial line; preserve preload, systemic vascular resistance, and sinus rhythm.
Uncertain symptom status or important associated disease, such as pulmonary hypertension, coronary disease, or atrial fibrillation	Obtain rapid multidisciplinary assessment and targeted optimization; avoid unnecessary testing-related delay.	Review pre-fracture symptoms, ventricular function, volume status, and disease control. Comorbidity alone does not mandate valve intervention.
Symptomatic severe stenosis, LVEF <50%, hemodynamic instability, or decompensated heart failure	Stabilize and urgently assess whether expedited TAVR is feasible and beneficial before fixation.	Balance the expected benefit of valve treatment against procedural risk and the consequences of delaying fracture repair. Valve intervention is not automatic.
Definitive valve intervention not feasible within an acceptable interval	Consider BAV as a temporary bridge in selected patients; alternatively, proceed to urgent fixation with enhanced monitoring when delay poses greater risk.	Evidence for routine preoperative BAV is limited and mixed. Individualize the decision with orthopedic surgery, anesthesia, and cardiology.

LVEF, left ventricular ejection fraction; TAVR, transcatheter aortic valve replacement; BAV, balloon aortic valvuloplasty. Summary of the management principles discussed in the text; decisions remain individualized. Sources[1-3,29,39,46,49]:

time sensitive and postponement greater than 24-48 hours can dramatically increase mortality and morbidities.[37]

Existing evidence on preoperative aortic valvular intervention for urgent non-cardiac surgery remains limited, but TAVR may provide definitive treatment and BAV may serve as a bridging option in selected patients.[44,49] TAVR has been shown to not increase risk of pursuing urgent non-cardiac surgery and cardiac related complications in 30-day post op.[46,50] Ferré et al. reported that preoperative BAV was associated with lower mortality on Kaplan-Meier survival analysis compared with no BAV (p=0.014), despite an increase in median time to operation of approximately 48 hours. The retrospective design and small sample limit causal interpretation.[49] BAV as a short-term bridging therapy can buy time and improve hemodynamics before TAVR or for urgent non-cardiac surgery.[51]

Overall, patients with asymptomatic, clinically compensated aortic stenosis without active comorbid conditions requiring stabilization can immediately proceed to hip fracture surgery under strict hemodynamic monitoring. Patients whose suitability for immediate surgery is uncertain require urgent multidisciplinary discussion, rapid risk stratification, and consideration of a TAVR workup when appropriate.[1] Patients with symptomatic severe aortic stenosis, hemodynamic instability, or significant ventricular dysfunction should undergo expedited multidisciplinary assessment to determine whether preoperative valve intervention is warranted. TAVR or balloon aortic valvuloplasty may be considered in selected high-risk patients when feasible without unacceptable delay to fracture fixation. Alternatively, urgent orthopedic surgery may proceed with appropriate hemodynamic monitoring and optimization when the risks of delaying fracture repair outweigh the potential benefits of prior valve intervention.[1] When definitive valve intervention is not feasible and the anticipated benefit outweighs procedural risk and delay, BAV may be considered as a temporary bridge in selected patients; it is not routinely required.[1] Table 1 summarizes the principal management pathways.

CHOOSING ANESTHETIC TECHNIQUE

The choice of anesthetic techniques for patients with aortic stenosis undergoing hip fracture surgery is complex and dependent on their ability to maintain hemodynamic stability, postoperative recovery, and mortality outcomes.[52] Patients with aortic stenosis have major fixed outflow obstruction that significantly reduces their ability to increase stroke volume to compensate for increased cardiac demands, abrupt changes in afterload, and induced hypotension caused by anesthetic agents.[1] Recent literature indicated there are no superior anesthetic techniques when comparing neuraxial versus general anesthesia, similar findings are also observed between regional versus general anesthesia.[52-54]

General anesthesia offers control over ventilation and anesthetic depth, rapid induction, and a predictable environment for hip fracture surgery.[55] Patients may prefer to be completely unconscious, and this reduces any concerns about intraoperative awareness or positioning issues during prolonged procedures.[53] General anesthesia also provides definitive airway management and serves as an alternative for patients who cannot receive spinal blockade.[52] However, patients with aortic stenosis have decreased tolerability for anesthetic agents and post-induction complications such as hypotension, tachycardia, myocardial depression, and reduction of sinus node automaticity.[3,46,56] This greater intolerance for hemodynamic instability in aortic stenosis has been shown to be associated with increased postoperative 5- and 30-day mortality.[57] Compared to regional and neuraxial anesthesia, general anesthesia also led to higher rates of respiratory complications, acute

renal failure, acute myocardial infarction, and pneumonia.[56]

The decision to proceed with general anesthesia should be discussed on a case-by-case basis with emphasis on avoiding drastic drops in blood pressure during the induction period and providing adequate intraoperative cardiac support with invasive hemodynamic monitoring.[3] In case of hypotension, vasopressors with higher affinity for alpha receptors (phenylephrine and norepinephrine) are favored to restore systemic vascular resistance without inducing tachycardia.[3] While short-acting calcium channel blockers are preferred over negative inotropes to lower blood pressure.[3] For induction agents, cipepofol has recently emerged as a superior choice compared to propofol in reducing post-induction hypotension incidence (70.5% vs. 88.5%, p=0.01) and providing hemodynamic stability in patients with aortic stenosis.[58] However, larger studies are needed to clarify short- and long-term patient benefits.[58]

Traditionally, neuraxial anesthesia has been contraindicated in patients with aortic stenosis due to theoretical risks of sympathetic blockade, but recent literature has challenged that viewpoint and demonstrated neuraxial anesthesia as a great option for patients undergoing non-cardiac surgery.[56,59] Other concerns include patients' awareness and their ability to tolerate the orthopedic procedure while being conscious. This is routinely addressed in neuraxial anesthesia by providing sedation with close titration to ensure patient comfort and to preserve adequate oxygenation and ventilation.[52]

Neuraxial options include single-shot spinal, combined spinal-epidural (CSE), and epidural. Single-shot spinal is a straightforward technique that involves delivering a bolus of anesthetic agents that can take effect rapidly. This technique is often avoided due to the sudden sympathetic blockade effect that can compromise right ventricular function by decreasing mean arterial pressure (MAP) and inducing bradycardia.[60] Epidurals allow for slow, continuous titration of anesthetic dosing; the gradual onset of this technique can mitigate abrupt changes in hemodynamics compared to single-shot spinal.[60] A CSE introduces a lower initial intrathecal dose of anesthesia and allows for continuous titration of anesthesia through epidural access, therefore utilizing the advantages of the techniques mentioned above.[61]

In patients with aortic stenosis undergoing urgent non-cardiac surgery, recent evidence has suggested that neuraxial anesthesia should not be contraindicated and is a viable alternative to general anesthesia.[56] A common principle when proceeding with neuraxial anesthesia is to mitigate abrupt drops in blood pressure and provide adequate hemodynamic support with fluid and vasopressors.[59,61] Thus, slow titration and continuous anesthetic techniques such as epidural and CSE should be selected over single-shot spinal anesthesia.[60]

Peripheral nerve blocks act as an opioid-sparing adjunct to rather than being the standalone anesthesia for patients having hip fractures.[62] Peripheral nerve block techniques regularly performed for hip fractures are the femoral nerve blocks (FNB), fascia iliaca compartment blocks (FICB), and pericapsular nerve group block (PENG).[62] Compared to traditional pain control methods, nerve blocks reduce the rates of common complications associated with opioids such as delirium, respiratory depression, excessive sedation and chest infection.[62,63] FNB is found to have greater pain control, fewer side effects, less need for rescue analgesics compared to fentanyl for patients with hip fracture pain.[64] Further benefits from nerve blocks include earlier time to mobilization, reduced pain on movement, and shorter hospitalization.[63,65,66] Interestingly, the PENG block has been shown to provide superior pain control compared to FICB and FNB.[62,67]

The best anesthetic techniques for patients undergoing hip fracture surgery remain uncertain as current evidence has shown no significant difference between general vs. neuraxial anesthesia. The Regional versus General Anesthesia for Promoting Independence after Hip Fracture (REGAIN; n=1600) and Regional Anesthesia vs General Anesthesia (RAGA; n=950) trials collectively indicated no significant difference in mortality, ambulatory recovery, length of hospital stay, and adverse outcomes between general and neuraxial anesthesia.[52,68] These findings must be carefully applied to aortic stenosis patients because of the reduced ability to compensate for any cardiovascular changes under anesthesia. Recent literature has shown a transition away from historical views on neuraxial anesthesia being contraindicated in patients with aortic stenosis and current guidelines have shown no preference between general anesthesia and neuraxial anesthesia for non-cardiac surgery in this population.[2,59]

Ultimately, the choice of anesthesia should be an individualized decision made based on a multidisciplinary team discussion, patients' severity of aortic stenosis, hemodynamic stability, and patients' preferences.[2] Regardless of the techniques chosen, invasive monitoring is necessary for rapid response to any physiological changes. General anesthesia requires careful induction, while neuraxial anesthesia requires slow titration to avoid hypotension, tachycardia, and other cardiac complications. Peripheral nerve blocks should be used as an adjunct, when possible, to aid in patient pain control and recovery.

INTRAOPERATIVE MANAGEMENT

The primary goals of intraoperative management in patients with severe aortic stenosis are to maintain preload, coronary perfusion, cardiac output, sinus rhythm, and systemic vascular resistance.[69] Severe aortic stenosis produces a relatively fixed obstruction to left ventricular outflow, while the associated concentric hypertrophy and diastolic dysfunction make cardiac output highly dependent on adequate preload, sinus rhythm, and systemic vascular resistance.[61,69] Consequently, intraoperative hypotension, hypovolemia, tachycardia, and bradycardia can result in decreased coronary perfusion and myocardial ischemia.[61,69] To achieve these goals, both the AHA/ACC and ESC/EACTS guidelines have emphasized strict intraoperative hemodynamic monitoring for patients with severe aortic stenosis.[2,39]

The standard monitors as defined by the American Society of Anesthesiologists guidelines should be used intraoperatively for patients with severe aortic stenosis. These monitors include electrocardiography, pulse oximetry, capnometry, blood pressure, and temperature.[70] On ECG, the V5 lead has high sensitivity to myocardial ischemia, with up to 90% sensitivity when used in combination with V4.[71] Inferior leads II, III, and aVF are sensitive in detecting arrhythmias.[71] Avoidance of hypothermia is likewise important as shivering can lead to myocardial oxygen supply-demand mismatch.[2,61] The use of intraarterial blood pressure monitoring is also indicated in patients with significant valvular disease undergoing non-cardiac surgery and in procedures where large hemodynamic changes are anticipated.[61,72] Intraarterial blood pressure monitoring allows for prompt recognition of hypotension and facilitates rapid titration of vasopressor therapy. A central venous catheter may also be considered when peripheral access is inadequate, prolonged vasopressor infusion is expected, or significant fluid shifts and hemodynamic instability are expected.[69,71,73] While not generally required for hip fracture surgery, PA catheterization should be selectively used based on the patient's cardiopulmonary status and expected hemodynamic disturbances during surgery. Some situations that may warrant use of PA catheterization in a patient with severe aortic stenosis undergoing hip surgery include anticipated hemodynamic instability, right-sided heart failure, or pulmonary hypertension.[2] TEE may provide valuable real-time information on ventricular function, valvular disease, and unexplained hypotension. The 2024 AHA/ACC guideline considers intraoperative TEE reasonable in assessing unexplained hemodynamic instability, but not its routine use in patients undergoing non-cardiac surgery without significant risk for hemodynamic compromise.[2]

Maintenance of MAP and systemic vascular resistance is central to the intraoperative management of severe aortic stenosis. This is because coronary perfusion, which occurs primarily during diastole for the left ventricle, depends on aortic diastolic pressures. The left ventricular hypertrophy in severe aortic stenosis increases the risk of myocardial infarction in the setting of hypotension and reduced coronary perfusion.[61] Hypotension, particularly on induction of general anesthesia, should be rapidly treated with α-adrenergic agonists such as phenylephrine or norepinephrine.[72] Severe hypertension can also precipitate myocardial ischemia and can be treated with deepening anesthesia or administering short acting beta blockers if also tachycardic. The 2024 AHA/ACC recommends intraoperative MAP greater than 60 to 65 mmHg or systolic blood pressure greater than 90 mmHg for patients undergoing non-cardiac surgery.[2] In patients with severe aortic stenosis, individualized pressure targets based on baseline blood pressures may be appropriate. Furthermore, given the poorly compliant left ventricle and impaired diastolic filling, it is also critical to maintain a full preload to maintain stroke volume in patients with severe aortic stenosis.[72]

Additionally, maintenance of sinus rhythm and avoiding significant fluctuations in heart rate are both essential to the intraoperative management of severe aortic stenosis. The stiff and hypertrophied left ventricle associated with severe aortic stenosis relies heavily on atrial contraction to achieve adequate ventricular filling.[69] The atrial kick accounts for around 30% of ventricular filling.[69,74] Loss of atrial kick, as occurs with atrial fibrillation, can therefore reduce ventricular filling and cardiac output.[72] The 2024 AHA/ACC guidelines recommend aggressively treating reversible causes of atrial fibrillation and initiating medications for rate and rhythm control. Cardioversion can be considered in cases of atrial fibrillation refractory to medications and with hemodynamic instability.[2] Furthermore, tachycardia and bradycardia should be avoided intraoperatively in patients with severe aortic stenosis. Tachycardia reduces diastolic filling time and coronary perfusion time. Reversible causes of tachycardia such as inadequate analgesia, hypovolemia, anemia, and light anesthesia, should be promptly addressed. In severe aortic stenosis, cardiac output is increasingly dependent on rate because the relatively fixed outflow obstruction and stiff ventricle limit the ability to augment stroke volume. Consequently, significant bradycardia can reduce cardiac output.[69,72]

POSTOPERATIVE MANAGEMENT

Even with successful completion of hip fracture surgery in patients with severe aortic stenosis, the postoperative period represents a continued period of hemodynamic vulnerability. The effects of anesthetic agents, surgical blood loss, fluid shifts, pain, and surgical stress continue to persist outside of the operating room. In a large nationwide analysis of around 2.3 million patients who underwent hip fracture surgery, patients with aortic stenosis were found to have higher rates of postoperative mortality compared to those without aortic stenosis (3.3% vs. 1.57%, $p<0.001$).[45] Likewise, patients with aortic stenosis were associated with higher odds of postoperative acute myocardial infarction, acute renal failure, and cardiogenic shock.[45] Similarly, Rostagno et al. also found that patients with aortic stenosis had higher rates of postoperative myocardial infarction compared to controls (8.3% vs. 1.1%, $p<0.001$).[36] These findings highlight the importance of the postoperative period for patients with severe aortic stenosis after hip fracture surgery.

MONITORING

Although historical guidelines and practices have generally advocated for intensive monitoring after non-cardiac surgery in patients with severe valvular disease, there is a paucity of research demonstrating a clear benefit from routine postoperative ICU admission.[2,75] In a retrospective study of 66 patients with severe aortic stenosis undergoing hip fracture surgery, investigators compared clinical outcomes of 31 patients admitted to ICU versus 35 admitted to general wards postoperatively.[29] The clinical characteristics (atrial fibrillation, diabetes, heart failure, chronic kidney disease, dementia, coronary artery disease), number of patients with time-to-surgery <48 hours, and preoper-

ative echocardiographic parameters were not different between ICU and general wards groups. Overall, the study did not find a statistical difference in postoperative complications or in-hospital mortality between the ICU and general wards groups.[29] These results, as the authors also acknowledged, need to be interpreted cautiously as it could also be related to the multidisciplinary structure of their hospital wards unit.[29] Multidisciplinary team-based approaches to hip fracture management have been associated with improved outcomes.[76] These findings suggest that routine ICU admission for every patient with severe aortic stenosis after hip fracture surgery may not provide additional benefit and that postoperative disposition should be individualized. Patients with persistent hemodynamic instability, inotropic or vasopressor requirements, respiratory compromise, major intraoperative complications, or other indications may warrant ICU-level care. Conversely, for those patients who are hemodynamically stable, not on vasopressors or inotropes, and do not require ventilatory support, post-operative care in a step-down unit or general wards unit may be reasonable with close hemodynamic monitoring.

Thus, telemetry and close hemodynamic monitoring are important during the early postoperative period because patients with aortic stenosis are at risk for myocardial infarction, ischemic stroke, cardiogenic shock, and arrhythmias.[36,45,77] The 2024 AHA/ACC perioperative guidelines recommend specifically that patients with severe aortic stenosis should be monitored closely in the postoperative period to minimize risk of hypotension, excessive hypertension, tachycardia, hypervolemia, and hypovolemia.[2] Although there are no specific trials currently demonstrating that telemetry improves outcomes in patients with severe aortic stenosis, telemetry is a reasonable component of postoperative monitoring because of the increased risk for myocardial infarction and arrhythmia in this patient population. The duration of telemetry monitoring should be individualized to each patient. A shorter duration of monitoring would be reasonable for a patient who maintains normal sinus rhythm and has no signs of ischemic changes.

PAIN CONTROL

Adequate postoperative analgesia is crucial in patients with severe aortic stenosis after hip fracture surgery. Aside from patient discomfort, inadequate analgesia causes sympathetic activation, tachycardia, and hypertension. These changes can be particularly detrimental to patients with severe aortic stenosis, causing reduced coronary perfusion time and increasing myocardial oxygen demand. On the contrary, excessive opioid administration can cause hypotension, which reduces coronary perfusion pressure. The National Institute for Health and Care Excellence (NICE) hip fracture guideline recommends scheduled acetaminophen every 6 hours postoperatively, with additional immediate-release opioids if necessary.[78] Additionally, the NICE guideline also recommends consideration of nerve blocks to improve pain control while limiting opioid use.[78] In a randomized controlled trial of 161 hip fracture patients at three emergency departments in New York, patients who received a FNB followed by continuous FICB had statistically significantly lower post-operative pain scores, 33% less parenteral morphine sulfate requirements, and fewer opioid-related side effects such as nausea, sedation, or unclear thinking.[79] Furthermore, patients who received the nerve block had greater walking distances on postoperative day 3 and reported better walking and stair climbing at 6 weeks.[79] Although the initial single shot FNB was performed on presentation in the emergency department, the subsequent continuous FICB was inserted preoperatively and continued through the postoperative day 3.[79] Although this study is not specific to hip fracture patients with severe aortic stenosis, the findings still support regional anesthesia as a valuable tool as part of an opioid-sparing postoperative analgesia strategy.[79]

DELIRIUM PREVENTION

Furthermore, postoperative delirium is a frequent complication in older patients with hip fractures and has been associated with prolonged hospitalization, increased mortality, and poor recovery.[80] One single center study of hip fracture patients found that 48% experienced postoperative delirium.[81] Some risk factors for postoperative delirium in hip fracture patients include older age, cognitive impairment, higher aortic stenosis physical classification, sensory impairment, and frailty.[80,82] In the severe aortic stenosis hip fracture patient cohort described by Rostagno et al, postoperative delirium was associated with mortality, further highlighting the importance of delirium prevention.[29]

Prevention of postoperative delirium should focus on both non-pharmacological and pharmacological approaches. Tools such as the Age, WORLD backwards, Orientation, iLlness severity, Surgery-specific risk (AWOL-S) score offer clinicians an effective way to predict the risk of delirium.[80] Furthermore, multidisciplinary care models for patients following orthopedic surgery, such as orthogeriatric comprehensive care models, have been shown to significantly reduce prevalence of postoperative delirium.[80,83] These care models frequently emphasize identification of risk factors, optimization of nutrition and bowel function, pain management, and fluid management, and early mobilization.[80] The NICE hip fracture guideline recommends a multidisciplinary assessment on admission and continued multidisciplinary rehabilitation and review to recover mobility and independence.[78] The American Geriatric Society recommends interventions such as frequent cognitive reorientation, sleep optimization, early mobilization, use of sensory aids, nutrition and fluid optimization, effective pain control, and avoidance of deliriogenic medications (e.g., benzodiazepines, anticholinergics, diphenhydramine, and opioids), and adequate oxygenation.[84]

The current evidence on the most effective anesthetic technique to reduce risk of postoperative delirium has been largely mixed. One randomized controlled trial found no difference in risk of postoperative delirium in hip fracture patients who received spinal anesthesia versus general anesthesia.[52] Similarly, another large randomized controlled trial by Li et al. found no statistically significant difference in postoperative delirium in the regional anesthesia

versus the general anesthesia group.[68] Regarding general anesthesia, the data supporting intravenous versus inhalational has also been mixed as it relates to reducing postoperative delirium. Some studies have found that inhalational anesthesia may increase the risk of postoperative delirium, whereas others found that inhalational anesthesia reduced it.[85,86]

Lastly, peripheral nerve blocks may also contribute to delirium prevention by reducing postoperative pain and opioid use. A large meta-analysis of 19 randomized controlled trials found that peripheral nerve blocks lowered the postoperative delirium incidence on postoperative day three.[87] However, this effect was only seen in patients without underlying cognitive impairment and when fascia iliaca block or a femoral nerve block were performed.[87]

EARLY MOBILIZATION

Lastly, early mobilization is central to postoperative recovery following hip fracture surgery. As aforementioned, early mobilization can serve as a tool for preventing postoperative delirium.[84] Prolonged immobility after hip fracture surgery increases risk of venous thromboembolism, pulmonary complications, deconditioning, pressure injuries, and poor recovery. Current NICE hip fracture guidelines recommend physiotherapy assessment and daily mobilization starting the day after surgery.[78] A large meta-analysis of 13 studies found that early postoperative mobilization has been associated with lower 30-day mortality (OR 0.35, $p<0.001$) and fewer postoperative complications (OR 0.43, $p<0.001$).[88] Therefore, early mobilization should occur as early as clinically feasible after confirming hemodynamic stability and with gradual progression.

CONCLUSION

Severe aortic stenosis in the setting of an acute hip fracture presents a challenging balance between the cardiovascular risks of proceeding with surgery and the consequences of delaying fracture fixation. Severe aortic stenosis alone should not automatically prompt postponement of urgent hip fracture surgery or mandate preoperative valve intervention. Rather, management should be individualized according to symptom status, ventricular function, severity of valvular obstruction, hemodynamic stability, comorbid disease, and the feasibility and timing of aortic valve intervention. Patients with asymptomatic, compensated aortic stenosis and preserved ventricular function may often proceed with timely hip fracture fixation when accompanied by careful hemodynamic optimization and appropriate monitoring, whereas symptomatic patients, those with ventricular dysfunction or hemodynamic instability, and those with severe disease may warrant expedited evaluation for valve intervention when feasible. When surgery proceeds without prior valve intervention, preservation of preload, systemic vascular resistance, coronary perfusion, and sinus rhythm remains central to perioperative management. The choice of general, neuraxial, and peripheral regional techniques should be individualized rather than dictated by historical contraindications, with attention to avoiding abrupt changes in vascular tone and cardiac filling. Ultimately, the management of these patients requires coordinated decision-making among orthopedic surgery, anesthesia, cardiology, and other relevant specialists, with the goal of minimizing delays while maintaining cardiovascular stability throughout the perioperative period.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Lisa Wofford (Chief Anesthesiologist at Ben Taub General Hospital) and Dr. Lee Chang (Anesthesiology Residency Program Director at Baylor College of Medicine) for their guidance and continued support in developing this literature review.

Submitted: October 14, 2026 EST. Accepted: October 24, 2026 EST. Published: November 16, 2026 EST.

REFERENCES

1. Terré JA, Torrado J, George I, et al. Aortic Stenosis Management in Patients With Acute Hip Fracture. *JACC Adv*. 2024;3(5):100912. doi:10.1016/j.jacadv.2024.100912. PMID:38939644

2. Writing Committee Members, Thompson A, Fleischmann KE, et al. 2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2024;84(19):1869-1969. doi:10.1016/j.jacc.2024.06.013. PMID:39320289

3. Writing Committee Members, Otto CM, Nishimura RA, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2021;77(4):e25-e197. doi:10.1016/j.jacc.2020.11.018. PMID:33342586

4. Reynolds EE, Baron SJ, Kaneko T, Libman H. Transcatheter Aortic Valve Replacement Versus Surgical Aortic Valve Replacement: How Would You Manage This Patient With Severe Aortic Stenosis? : Grand Rounds Discussion From Beth Israel Deaconess Medical Center. *Ann Intern Med*. 2021;174(4):521-528. doi:10.7326/M21-0724. PMID:33844572

5. Andaloro S, Cacciatore S, Risoli A, et al. Hip Fracture as a Systemic Disease in Older Adults: A Narrative Review on Multisystem Implications and Management. *Med Sci (Basel)*. 2025;13(3):89. doi:10.3390/medsci13030089. PMID:40700118

6. Haleem S, Choudri MJ, Kainth GS, Parker MJ. Mortality following hip fracture: Trends and geographical variations over the last SIXTY years. *Injury*. 2023;54(2):620-629. doi:10.1016/j.injury.2022.12.008. PMID:36549980

7. Dakhil S, Saltvedt I, Benth JS, et al. Longitudinal trajectories of functional recovery after hip fracture. *PLoS One*. 2023;18(3):e0283551. doi:10.1371/journal.pone.0283551. PMID:36989248

8. Sarode AL, Su E, Drost J, Evan M, Haselton L, Blecker N. The economic burden of hip fractures in the geriatric population by mental health illness and substance Use Status: National estimates 2016 to 2020. *Injury*. 2025;56(10):112615. doi:10.1016/j.injury.2025.112615. PMID:40743636

9. van Rijckevorsel VAJIM, de Jong L, Verhofstad MHJ, Roukema GR, Dutch Hip Fracture Registry Collaboration. Influence of time to surgery on clinical outcomes in elderly hip fracture patients: an assessment of surgical postponement due to non-medical reasons. *Bone Joint J*. 2022;104-B(12):1369-1378. doi:10.1302/0301-620X.104B12.BJJ-2022-0172.R2. PMID:36453044

10. George J, Sharma V, Farooque K, Mittal S, Trikha V, Malhotra R. The Impact of Surgical Timing of Hip Fracture on Mortality: Do the Cause and Duration of Delay Matter? *Hip Pelvis*. 2023;35(3):206-215. doi:10.5371/hp.2023.35.3.206. PMID:37727296

11. Demir T, Irgit KS, Seyhan E, Cimen O, Karaca H. Beyond the guidelines: outcomes of extremely delayed hip fracture surgery in elderly. *BMC Musculoskelet Disord*. 2025;26(1):794. doi:10.1186/s12891-025-09062-4. PMID:40819048

12. Yu Y, Zheng P. Determination of risk factors of postoperative pneumonia in elderly patients with hip fracture: What can we do? *PLoS One*. 2022;17(8):e0273350. doi:10.1371/journal.pone.0273350. PMID:35998192

13. Hamdan M, Haddad BI, Almohtasib J, et al. Postoperative pneumonia after femoral fracture surgery: an in-depth retrospective analysis. *BMC Musculoskelet Disord*. 2024;25(1):413. doi:10.1186/s12891-024-07529-4. PMID:38802816

14. Gao YC, Zhang YW, Shi L, et al. What are Risk Factors of Postoperative Pneumonia in Geriatric Individuals after Hip Fracture Surgery: A Systematic Review and Meta-Analysis. *Orthop Surg*. 2023;15(1):38-52. doi:10.1111/os.13631. PMID:36519396

15. Taoka T, Ohmori T, Kanazawa T, Toda K, Ishihara T, Ito Y. Delayed surgery after hip fracture affects the incidence of venous thromboembolism. *J Orthop Surg Res*. 2023;18(1):630. doi:10.1186/s13018-023-04122-8. PMID:37641109

16. de Haan E, van Rijckevorsel VAJIM, Bod P, Roukema GR, de Jong L, Dutch Hip Fracture Registry Collaboration (DHFR). Delirium After Surgery for Proximal Femoral Fractures in the Frail Elderly Patient: Risk Factors and Clinical Outcomes. *Clin Interv Aging*. 2023;18:193-203. doi:10.2147/CIA.S390906. PMID:36818548

17. Elete AR, Panwar Y, Dannaway J, Chen J, Thomas B. Assessing operative delay and complications in hip fracture patients on anticoagulants and antiplatelets. *SAGE Open Med*. 2023;11:20503121231162410. doi:10.1177/20503121231162410. PMID:36993781

18. Kristan A, Omahen S, Tosounidis TH, Cimerman M. When does hip fracture surgery delay affects the length of hospital stay? *Eur J Trauma Emerg Surg*. 2022;48(2):701-708. doi:10.1007/s00068-020-01565-0. PMID:33388817

19. Mitchell SM, Chung AS, Walker JB, Hustedt JW, Russell GV, Jones CB. Delay in Hip Fracture Surgery Prolongs Postoperative Hospital Length of Stay but Does Not Adversely Affect Outcomes at 30 Days. *J Orthop Trauma*. 2018;32(12):629-633. doi:10.1097/BOT.0000000000001306. PMID:30299378

20. Moja L, Piatti A, Pecoraro V, et al. Timing matters in hip fracture surgery: patients operated within 48 hours have better outcomes. A meta-analysis and meta-regression of over 190,000 patients. *PLoS One*. 2012;7(10):e46175. doi:10.1371/journal.pone.0046175. PMID:23056256

21. Warren M, Bretherton C, Parker M. Delay to surgery beyond 12 hours is associated with increased hip fracture mortality. *Eur J Orthop Surg Traumatol*. 2024;34(6):2973-2980. doi:10.1007/s00590-024-03997-5. PMID:38844565

22. Bennett A, Li H, Patel A, et al. Retrospective Analysis of Geriatric Patients Undergoing Hip Fracture Surgery: Delaying Surgery Is Associated With Increased Morbidity, Mortality, and Length of Stay. *Geriatr Orthop Surg Rehabil*. 2018;9:2151459318795260. doi:10.1177/2151459318795260. PMID:30245906

23. Aachi M, Krishna CM. Impact of injury-to-admission interval on postoperative outcomes following surgical management of hip fractures: A retrospective cohort study. *Journal of Orthopaedic Reports*. 2026;5(4):101021. doi:10.1016/j.jorep.2026.101021

24. Zhang WS, Shao XL, Yang Z, Zhang BF. The 24-Hour Window: How Time to Admission Reshapes the Impact of Surgical Delay on Mortality in Elderly Hip Fracture. *J Clin Med*. 2026;15(14):5685. doi:10.3390/jcm15145685. PMID:42513599

25. Kita T, Funamoto T, Mori H, et al. Early surgery within 48 h for post-injury hip fractures improved clinical outcomes. *J Orthop Sci*. 2026;31(1):219-225. doi:10.1016/j.jos.2025.05.008. PMID:40615285

26. Lin CC, Qureshi I, Richardson MA, Anil U, Egol KA. Demographics, disparities and delays: why can't geriatric hip fractures get fixed within one day? *Orthop Traumatol Surg Res*. Published online May 4, 2026:104735. doi:10.1016/j.otsr.2026.104735. PMID:42092689

27. Grimes JP, Gregory PM, Noveck H, Butler MS, Carson JL. The effects of time-to-surgery on mortality and morbidity in patients following hip fracture. *Am J Med*. 2002;112(9):702-709. doi:10.1016/s0002-9343(02)01119-1. PMID:12079710

28. Peters AS, Duggan JP, Trachiotis GD, Antevil JL. Epidemiology of Valvular Heart Disease. *Surg Clin North Am*. 2022;102(3):517-528. doi:10.1016/j.suc.2022.01.008. PMID:35671771

29. Rostagno C, Cartei A, Rubbieri G, et al. Hip Fracture Surgery in Severe Aortic Stenosis: A Study of Factors Affecting Mortality. *Clin Interv Aging*. 2022;17:1163-1171. doi:10.2147/CIA.S360538. PMID:35957924

30. Joseph J, Naqvi SY, Giri J, Goldberg S. Aortic Stenosis: Pathophysiology, Diagnosis, and Therapy. *Am J Med*. 2017;130(3):253-263. doi:10.1016/j.amjmed.2016.10.005. PMID:27810479

31. Clavel MA, Tastet L, Pibarot P. Cardiac remodelling in aortic stenosis. *Arch Cardiovasc Dis*. 2026;119(1):32-38. doi:10.1016/j.acvd.2025.11.004. PMID:41698772

32. Mancusi C, Bahlmann E, Basile C, Gerdts E. New Evidence About Aortic Valve Stenosis and Cardiovascular Hemodynamics. *High Blood Press Cardiovasc Prev*. 2022;29(3):231-237. doi:10.1007/s40292-022-00520-x. PMID:35438477

33. Eichlseder M, Schreiber N, Flick M, Sartori S. Perioperative management of adults with heart valve disease having noncardiac surgery: a narrative review. *Curr Opin Anaesthesiol*. 2026;39(3):371-380. doi:10.1097/ACO.0000000000001643. PMID:41885311

34. Cronin PK, Olson JJ, Harris MB, Weaver MJ. Severe aortic stenosis is associated with perioperative mortality in proximal femur fracture patients. *OTA Int*. 2020;3(2):e054. doi:10.1097/OI9.0000000000000054. PMID:33937694

35. Keswani A, Lovy A, Khalid M, et al. The effect of aortic stenosis on elderly hip fracture outcomes: A case control study. *Injury*. 2016;47(2):413-418. doi:10.1016/j.injury.2015.10.015. PMID:26556487

36. Rostagno C, Ranalli C, Polidori G, Cartei A, Boccaccini A, Peris A. Outcome in elderly patients with aortic stenosis undergoing hip fracture surgery. Results may suggest a different postoperative strategy? *Trauma Surg Acute Care Open*. 2019;4(1):e000218. doi:10.1136/tsaco-2018-000218. PMID:30729173

37. Klestil T, Röder C, Stotter C, et al. Impact of timing of surgery in elderly hip fracture patients: a systematic review and meta-analysis. *Sci Rep*. 2018;8(1):13933. doi:10.1038/s41598-018-32098-7. PMID:30224765

38. Playford D, Schwarz N, Chowdhury E, et al. Comorbidities and Symptom Status in Moderate and Severe Aortic Stenosis: A Multicenter Clinical Cohort Study. *JACC Adv*. 2023;2(4):100356. doi:10.1016/j.jacadv.2023.100356. PMID:38938261

39. Praz F, Borger MA, Lanz J, et al. 2025 ESC/EACTS Guidelines for the management of valvular heart disease. *Eur Heart J*. 2025;46(44):4635-4736. doi:10.1093/eurheartj/ehaf194. PMID:40878295

40. Singh M, Alexander K, Roger VL, et al. Frailty and its potential relevance to cardiovascular care. *Mayo Clin Proc*. 2008;83(10):1146-1153. doi:10.4065/83.10.1146. PMID:18828975

41. Johnson N, Qu J, Wagatsuma K, et al. Frailty and cardiovascular disease: a bidirectional relationship with clinical implications. *Front Cardiovasc Med*. 2025;12:1684701. doi:10.3389/fcvm.2025.1684701. PMID:41282339

42. Saad BN, Menken LG, Keller DM, et al. Does a delay to surgery for preoperative echocardiogram affect outcomes in patients with hip fracture? *OTA Int*. 2024;7(3):e338. doi:10.1097/OI9.0000000000000338. PMID:38863460

43. Welford P, Jones CS, Davies G, et al. The association between surgical fixation of hip fractures within 24 hours and mortality : a systematic review and meta-analysis. *Bone Joint J*. 2021;103-B(7):1176-1186. doi:10.1302/0301-620X.103B7.BJJ-2020-2582.R1. PMID:34192937

44. Place A, Rodrigues TS, Naimo PS, et al. Peri-operative risk of non-cardiac surgery in patients with aortic stenosis: a systematic review and meta-analysis. *Anaesthesia*. 2026;81(4):570-579. doi:10.1111/anae.70084. PMID:41388337

45. Hassan S, Anwar W, Mehta S, Hanif MI, Kamouh A, Blood AJ. Postoperative outcomes, predictors and trends of mortality and morbidity in patients undergoing hip fracture surgery with underlying aortic stenosis: a nationwide inpatient sample analysis. *BMC Cardiovasc Disord*. 2023;23(1):535. doi:10.1186/s12872-023-03584-2. PMID:37919652

46. Herrera RA, Smith MM, Mauermann WJ, Nkomo VT, Luis SA. Perioperative management of aortic stenosis in patients undergoing non-cardiac surgery. *Front Cardiovasc Med*. 2023;10:1145290. doi:10.3389/fcvm.2023.1145290. PMID:37089878

47. Laterra G, Agnello F, Strazzieri O, et al. Management of Asymptomatic Severe Aortic Stenosis: Current Evidence and Future Directions. *J Clin Med*. 2025;14(21):7549. doi:10.3390/jcm14217549. PMID:41226944

48. Lee G, Chikwe J, Milojevic M, et al. ESC/EACTS vs. ACC/AHA guidelines for the management of severe aortic stenosis. *Eur Heart J*. 2023;44(10):796-812. doi:10.1093/eurheartj/ehac803. PMID:36632841

49. Ferré F, Viarnes M, Martin C, et al. Is preoperative balloon aortic valvuloplasty of interest for severe aortic stenosis in hip fracture surgery? *Injury*. 2021;52(6):1438-1444. doi:10.1016/j.injury.2020.09.048. PMID:32998825

50. Ebrahimian S, Chervu N, Balian J, et al. Timing of Noncardiac Surgery Following Transcatheter Aortic Valve Replacement: A National Analysis. *JACC Cardiovasc Interv*. 2024;17(14):1693-1704. doi:10.1016/j.jcin.2024.04.049. PMID:38904608

51. Kleczynski P, Kulbat A, Brzychczy P, et al. Balloon Aortic Valvuloplasty for Severe Aortic Stenosis as Rescue or Bridge Therapy. *J Clin Med*. 2021;10(20):4657. doi:10.3390/jcm10204657. PMID:34682783

52. Neuman MD, Feng R, Carson JL, et al. Spinal Anesthesia or General Anesthesia for Hip Surgery in Older Adults. *N Engl J Med*. 2021;385(22):2025-2035. doi:10.1056/NEJMoa2113514. PMID:34623788

53. Viderman D, Aubakirova M, Nabidollayeva F, Abdildin YG. The Analysis of Multiple Outcomes between General and Regional Anesthesia in Hip Fracture Surgery: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J Clin Med*. 2023;12(24):7513. doi:10.3390/jcm12247513. PMID:38137582

54. Meermans G, van Egmond JC. Management and optimisation in the preoperative phase for patients with a fractured hip. *EFORT Open Rev*. 2026;11(5):390-403. doi:10.1530/EOR-2026-0044. PMID:42065220

55. Zheng X, Tan Y, Gao Y, Liu Z. Comparative efficacy of Neuraxial and general anesthesia for hip fracture surgery: a meta-analysis of randomized clinical trials. *BMC Anesthesiol*. 2020;20(1):162. doi:10.1186/s12871-020-01074-y. PMID:32605591

56. Tai YH, Chang CC, Yeh CC, Cherng YG, Chen TL, Liao CC. Adverse outcomes after noncardiac surgery in patients with aortic stenosis. *Sci Rep*. 2021;11(1):19517. doi:10.1038/s41598-021-98507-6. PMID:34593867

57. Griffiths R, Babu S, Dixon P, et al. Guideline for the management of hip fractures 2020: Guideline by the Association of Anaesthetists. *Anaesthesia*. 2021;76(2):225-237. doi:10.1111/anae.15291. PMID:33289066

58. Ni T, Zhou X, Wu S, et al. Hemodynamic Impact of Cipepofol vs Propofol During Anesthesia Induction in Patients With Severe Aortic Stenosis: A Randomized Clinical Trial. *JAMA Surg*. 2025;160(7):763-770. doi:10.1001/jamasurg.2025.1299. PMID:40397427

59. Tabrizi NS, Demos RA, Schumann R, Musuku SR, Shapeton AD. Neuraxial Anesthesia in Patients With Aortic Stenosis: A Systematic Review. *J Cardiothorac Vasc Anesth*. 2024;38(2):505-516. doi:10.1053/j.jvca.2023.09.027. PMID:37880038

60. Rajagopal S, Ruetzler K, Ghadimi K, et al. Evaluation and Management of Pulmonary Hypertension in Noncardiac Surgery: A Scientific Statement From the American Heart Association. *Circulation*. 2023;147(17):1317-1343. doi:10.1161/CIR.0000000000001136. PMID:36924225

61. Cruvinel C. The anesthetic challenges of managing patients with aortic stenosis for non-cardiac surgery. *Med Res Arch*. 2025;13(8). doi:10.18103/mra.v13i8.6899

62. Liu YT, Tovar Hirashima E, Yadav K. Peripheral Nerve Blocks for Hip Fractures. *JAMA*. 2025;333(23):2106-2107. doi:10.1001/jama.2025.0999. PMID:40126505

63. Guay J, Kopp S. Peripheral nerve blocks for hip fractures in adults. *Cochrane Database Syst Rev*. 2020;11(11):CD001159. doi:10.1002/14651858.CD001159.pub3. PMID:33238043

64. Altunbaş E, Kudu E, Unal E, Sanri E, Karacabey S, Gunduz OH. Femoral nerve block vs IV fentanyl for hip fracture pain in the emergency department: A randomized double-blind clinical trial. *Am J Emerg Med*. 2026;99:359-364. doi:10.1016/j.ajem.2025.10.044. PMID:41167010

65. Di Pietro S, Maffeis R, Jannelli E, et al. Comparing the pericapsular nerve group block and fascia iliaca block for acute pain management in patients with hip fracture: a randomised clinical trial. *Anaesthesia*. 2025;80(12):1484-1492. doi:10.1111/anae.16695. PMID:40727959

66. De Simone B, Chouillard E, Podda M, et al. The 2023 WSES guidelines on the management of trauma in elderly and frail patients. *World J Emerg Surg*. 2024;19(1):18. doi:10.1186/s13017-024-00537-8. PMID:38816766

67. Dolstra J, Vlieg H, Haak SL, Ter Avest E, Boerma EC, Lameijer H. PENG, fascia-iliaca compartment block or femoral nerve block for pain management of patients with hip fractures. *Am J Emerg Med*. 2025;96:15-24. doi:10.1016/j.ajem.2025.06.009. PMID:40513549

68. Li T, Li J, Yuan L, et al. Effect of Regional vs General Anesthesia on Incidence of Postoperative Delirium in Older Patients Undergoing Hip Fracture Surgery: The RAGA Randomized Trial. *JAMA*. 2022;327(1):50-58. doi:10.1001/jama.2021.22647. PMID:34928310

69. Schneider AC. A review of aortic stenosis: an anesthetic perspective. *J Anesth Crit Care Open Access*. 2018;10(6):262-264. doi:10.15406/jaccoa.2018.10.00401

70. American Society of Anesthesiologists Committee on Practice Parameters. Standards for basic anesthetic monitoring. American Society of Anesthesiologists. October 15, 2025. Accessed September 20, 2026. https://www.asahq.org/standards-and-practice-parameters/standards-for-basic-anesthetic-monitoring

71. Salter B, Mittnacht AJC, Denault AY, Reich DL, Kaplan JA, Badescu GC, et al. Monitoring of the heart and vascular system. In: *Kaplan's Cardiac Anesthesia: Perioperative and Critical Care Management*. Elsevier; 2023:283-330. doi:10.1016/B978-0-323-82924-3.00009-0

72. Paul A, Das S. Valvular heart disease and anaesthesia. *Indian J Anaesth*. 2017;61(9):721-727. doi:10.4103/ija.IJA_378_17. PMID:28970630

73. American Society of Anesthesiologists Committee on Economics. Statement on intravascular catheterization procedures. October 18, 2023. Accessed September 20, 2026. https://www.asahq.org/standards-and-practice-parameters/statement-on-intravascular-catheterization-procedures

74. Kurapati R, Heaton J, Lowery DR. Atrial Kick. In: *StatPearls [Internet]*. StatPearls Publishing; 2025. PMID:29494028

75. Kennon S, Archbold A. Expert Opinion: Guidelines for the Management of Patients with Aortic Stenosis Undergoing Non-cardiac Surgery: Out of Date and Overly Prescriptive. *Interv Cardiol*. 2017;12(2):133-136. doi:10.15420/icr.2017:20:2. PMID:29588742

76. Khasraghi FA, Christmas C, Lee EJ, Mears SC, Wenz JF Sr. Effectiveness of a multidisciplinary team approach to hip fracture management. *J Surg Orthop Adv*. 2005;14(1):27-31. PMID:15766439

77. Andersson C, Jørgensen ME, Martinsson A, et al. Noncardiac surgery in patients with aortic stenosis: a contemporary study on outcomes in a matched sample from the Danish health care system. *Clin Cardiol*. 2014;37(11):680-686. doi:10.1002/clc.22324. PMID:25224044

78. *Hip Fracture: Management*. National Institute for Health and Care Excellence (NICE); 2023. PMID:32073811

79. Morrison RS, Dickman E, Hwang U, et al. Regional Nerve Blocks Improve Pain and Functional Outcomes in Hip Fracture: A Randomized Controlled Trial. *J Am Geriatr Soc*. 2016;64(12):2433-2439. doi:10.1111/jgs.14386. PMID:27787895

80. Chen Y, Liang S, Wu H, et al. Postoperative delirium in geriatric patients with hip fractures. *Front Aging Neurosci*. 2022;14:1068278. doi:10.3389/fnagi.2022.1068278. PMID:36620772

81. Zywiel MG, Hurley RT, Perruccio AV, Hancock-Howard RL, Coyte PC, Rampersaud YR. Health economic implications of perioperative delirium in older patients after surgery for a fragility hip fracture. *J Bone Joint Surg Am*. 2015;97(10):829-836. doi:10.2106/JBJS.N.00724. PMID:25995494

82. Raats JW, van Eijsden WA, Crolla RM, Steyerberg EW, van der Laan L. Risk Factors and Outcomes for Postoperative Delirium after Major Surgery in Elderly Patients. *PLoS One*. 2015;10(8):e0136071. doi:10.1371/journal.pone.0136071. PMID:26291459

83. Igwe EO, Nealon J, Mohammed M, et al. Multi-disciplinary and pharmacological interventions to reduce post-operative delirium in elderly patients: A systematic review and meta-analysis. *J Clin Anesth*. 2020;67:110004. doi:10.1016/j.jclinane.2020.110004. PMID:32768990

84. American Geriatrics Society Expert Panel on Postoperative Delirium in Older Adults. American Geriatrics Society abstracted clinical practice guideline for postoperative delirium in older adults. *J Am Geriatr Soc*. 2015;63(1):142-150. doi:10.1111/jgs.13281. PMID:25495432

85. Saller T, Hubig L, Seibold H, et al. Association between post-operative delirium and use of volatile anesthetics in the elderly: A real-world big data approach. *J Clin Anesth*. 2022;83:110957. doi:10.1016/j.jclinane.2022.110957. PMID:36084424

86. Mei X, Zheng HL, Li C, et al. The Effects of Propofol and Sevoflurane on Postoperative Delirium in Older Patients: A Randomized Clinical Trial Study. *J Alzheimers Dis*. 2020;76(4):1627-1636. doi:10.3233/JAD-200322. PMID:32651322

87. Kim SY, Jo HY, Na HS, Han SH, Do SH, Shin HJ. The Effect of Peripheral Nerve Block on Postoperative Delirium in Older Adults Undergoing Hip Surgery: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J Clin Med*. 2023;12(7):2459. doi:10.3390/jcm12072459. PMID:37048543

88. Agarwal N, Feng T, Maclullich A, Duckworth A, Clement N. Early mobilisation after hip fracture surgery is associated with improved patient outcomes: A systematic review and meta-analysis. *Musculoskeletal Care*. 2024;22(1):e1863. doi:10.1002/msc.1863. PMID:38353351