Special Concerns of Intraoperative Management in Orthopedic Procedures

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Orthopedic Procedures

Total Hip Arthroplasty

Background

One of the most common procedures performed in the geriatric population is the total hip arthroplasty [1]. Depending upon the age range examined, it is either the second or the third most common procedure performed within the age range of 65–90+ years. In patients aged 18–64 years, it is not even in the top ten. In older females, the incidence of bone fractures is so common that it is higher than the aggregate incidence of stroke, breast cancer, and heart disease [2]. Further, 40% of those with hip fracture will require nursing care and 20% will be unable to return to normal ambulation.

With these statistics, it is little wonder that perioperative efforts are focused on either identifying preoperative risk modifiers or working to reduce known comorbidities [3]. While the definition of geriatric tends to focus on age alone, the last decade has seen an explosion in the understanding and need for further research to better quantify important modifiers of the aging process. Chief among these modifiers is the diagnosis of frailty [4–6].

While frailty is an easy concept to grasp, providing an exact definition is more tenuous and is beyond the scope of this chapter; however, we refer the reader to Chaps. 4 and 6 for a more thorough review of the concept of frailty and its application to perioperative care [4–8]. There are also several guidelines available to assist in the perioperative care of the geriatric patient for hip surgery both emergently and electively [7–11].

Finally, there are a few reviews that have examined the interaction or intersection of the Perioperative Surgical Home (PSH) as well as ERAS with the various Frailty scales and measures [12]. The application and expansion of the PSH as a concept has resulted in the development of several guidelines and protocols for the management of hip fracture in the elderly most notably in the UK [13]; however, the propagation of these guidelines was assisted by the development of an active surveillance database in use for over a decade [14, 15].

Interestingly, the initial guidelines [14] were designed following a Cochrane Review of outcomes following emergent hip fracture surgery [16] and include a recommendation for regional anesthesia (specifically subarachnoid anesthesia) even though this same review noted, "The effect of the removal of the oldest trial (McLaren 1978), which has an excessive mortality in the general anaesthesia group, also shows the weakness of the evidence." Despite this comment as well as others suggesting that there were issues in the review, it served as the basis for the guidelines evaluated in two recent Anaesthesia Sprint Audits of Practice (ASAP) [13, 17]. While the exact guidelines may or may not be ideal suggestions, the framework of those guidelines act as an excellent roadmap for examining important aspects of anesthetic care for hip fracture patients.

Intraoperative Care

The ASAP practice standards outline twelve standards for anesthetic practice [13]. While the first standard is not relevant to this chapter, those from two onward are.

> *Standard 2 – Spinal or epidural anaesthesia should be considered for all patientsStandard 11 – Hypotension should be avoided*

Standard 2 seems to be the most controversial of the standards suggested. The choice of either anesthetic category,

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general or regional, as a "safer" technique is not a universally accepted tenet. There are several papers and reviews regarding this subject that have been referred to previously, and almost all the reviews from the twenty-first century can find no difference in outcome regarding the selection of anesthetic approach. More importantly, whatever approach is chosen, it should be one that is familiar to the provider and provides for scrupulous attention to blood pressure management [17].

The management of blood pressure in the geriatric population is an important variable in determining outcome as has been suggested by a variety of studies throughout the last decade [18, 19]; however, there remains at least one major question. Regardless of the chosen level of hypotension (i.e., MAP < 55, MAP < 70, SBP < 20% below awake, etc.), the relationship between the chosen blood pressure and the chosen outcome (generally mortality, cardiac or neurological injury) has not been shown to be causal, only related. One possible hypothesis is that those patients with lesser hemodynamic reserves are the most likely to suffer hypotensive episodes and would also be more likely to suffer further insults over time. Developing hypotension in response to an anesthetic may simply be a biomarker for this poor reserve. Thus, while the avoidance of hypotension remains a paramount concern for anesthetic personnel, this may or may not reduce the likelihood of current or future events. This in no way should suggest therapeutic nihilism, but simply that we need to focus our attempts on examining the role of avoiding hypotension directly instead of looking for surrogate markers for poor outcomes.

Standard 3 – Spinal anesthetics should be administered using hyperbaric bupivacaine (< 10mg) with the patient positioned laterally (bad hip down)

Standard 4 – Co-administration of intrathecal opioids should be restricted to fentanyl

These standards suggest that if one wishes to use spinal anesthesia, reducing the dose of bupivacaine to less than 10 mg reduces hypotension [17, 20]. There is also a strong suggestion that hypobaric spinal techniques be avoided for the same reason (hypotension) [20, 21]. Adding fentanyl to the intrathecal mixture allows for improved postoperative analgesia with fewer issues of delirium, sedation, and respiratory depression. However, there is little direct evidence that fentanyl improves outcomes in hip fracture patients, so this recommendation represents a significant research opportunity. The Sprint Audit [13] demonstrated that fentanyl was used in only 32% of cases with the majority (~50%) adding diamorphine. Thus, it seems that many anesthetists do not follow this practice which suggests that there should be a room for further exploration.

Standard 5 – If sedation is required, this should be midazolam or propofol

The advantage of both propofol and midazolam lie primarily in their pharmacokinetic profiles and their wide safety margins when used in the geriatric population [22]. There is a general sense that geriatric patients tend to meet discharge criteria post sedation more quickly following propofol compared to midazolam; however, the data show small absolute differences (17.6 vs. 10.1 min for midazolam vs. propofol, respectively); thus, this may not be relevant clinically [22]. This finding is similar to that of their younger brethren (10.4 vs. 4.2 min for midazolam vs. propofol, respectively) [23]. Intraoperative amnesia is more complete following the use of midazolam [23], but whether this is a crucial outcome to the geriatric patient is not clear (patient satisfaction scores of 4.6 vs. 4.7 for midazolam vs. propofol, respectively) [22]. In the Sprint Audit [13], oversedation was common and may have contributed to hypotension; thus, tight control of sedation level is necessary to avoid this outcome. Further, the Audit also suggested that the use of propofol was associated with a reduced incidence of postoperative confusion compared to benzodiazepines and opiates [13].

Ketamine is frequently used for sedation during spinal anesthesia primarily for its salutary hemodynamic effects. Unfortunately, there is a fine line between the dosing for sedation and the avoidance of postoperative confusion [13]. It has been suggested that when combined with general anesthesia at a dose of 0.5 mg/kg, ketamine does not increase the incidence of postoperative cognitive dysfunction (POCD) at days 1 and 6 [24].

Standard 6 – Supplemental oxygen should always be provided

The use of supplemental oxygen is based on several observations. The first is that the implementation of spinal anesthesia is associated with sedation independent of anesthetic agents [25, 26]. In addition, regional oxygen saturation falls below baseline levels in patients receiving subarachnoid anesthetics with or without supplemental sedation [27]. Thus, the addition of supplemental oxygen seems both prudent and perspicacious. Further, because regional cerebral oxygen saturations are associated with that of peripheral oxygen saturations [28], the use of supplemental oxygen in concentrations higher than that obtained with nasal cannula is highly recommended.

Standard 7 – Inhalational agents should be considered for the induction of general anaesthesia.

This standard could be interpreted exactly as it is written, or with some license, it could also be interpreted as an admonition to avoid excessive administration of anesthetic agents and use a deliberate and watchful induction technique. These authors prefer the latter interpretation. Indeed, the outcome of the Audit suggests that most anesthetists also believe in the latter interpretation [13]. Fully 93% of those audited pursued an intravenous induction rather than an inhalational one. We are sure that if the question, "Did you consider the use of inhalational agents for induction?" was asked, most of that 93% would say, "Sure, I considered it for about 10 s and then reached for my trusted intravenous agent." Slow gentle inhalational inductions with sevoflurane are hemodynamically more stable than rapid intravenous inductions by both the nature of the rapidity of the transition from awake to anesthetized as well as the maintenance of spontaneous ventilation (see Standard 8). The important take away for the readers is that one should use the method most familiar to them with the caveat that there are well-established nomograms and guidelines for the reduction in dosing of anesthetic agents in the geriatric population [8, 29, 30].

Standard 8 – Spontaneous ventilation should be used in preference to mechanical ventilation

This is also a controversial recommendation as there are multiple reasons to select endotracheal management (ET) in preference to either LMA or mask supplementation. ET management reduces the risk of aspiration and allows for rapid control of the airway should the patient require urgent intervention. While spontaneous ventilation is not impossible with ET management, it increases both the work of breathing and the risk of hypoventilation for this reason (unless supplemented with pressure support). Spontaneous ventilation does allow for enhanced matching of ventilation and perfusion and is generally associated with decreased degrees of hypotension.

In the recent Audit [13], this recommendation was not as controversial as the previous standard but was clearly not followed in all or even most cases. Among those patients who received general anesthesia with an ET tube (44.2% of cases), 81% were paralyzed and mechanically ventilated, 9% were non-paralyzed but mechanically ventilated, 9% were not recorded or other, and in NONE of the cases, spontaneous ventilation was used. In those patients, whose airway was managed with an LMA (51% of cases), spontaneous ventilation was used in 73% of those cases, non-paralyzed but mechanically ventilated in 13%, and paralyzed and mechanically ventilated in slightly less than 9%. This suggests that less than half of all patients were allowed to breathe spontaneously.

Standard 9 – Consider intraoperative nerve blocks for all patients undergoing surgery

The use of peripheral nerve blocks (PNB) for all types of surgery and all ages including the geriatric group is increasing worldwide [31]. The chief advantage of these approaches is the reduction in the need for parenteral and oral opiates for managing analgesia. However, when they are placed immediately prior to surgery they also reduce the dose of anesthetic needed and can accelerate the rate of discharge from the PACU or ambulatory surgery [31]. Further, they can also assist in positioning the patient for subarachnoid anesthesia if placed prior to administration.

In the Audit [13], PNBs were used in 56% of patients and most (54%) were administered without the need for either ultrasound guidance or nerve stimulation. This was due in part to the use of fascia iliaca block in 56% of patients, instead of the more traditional (in the US) 3-in-1 (lateral cutaneous, obturator, and femoral nerve) or psoas compartment block. The fascia iliaca block, while not providing comparable analgesia to the 3-in-1 block, is easier to perform using landmark techniques, and this may explain its more common appearance in the Audit. Ultrasound guidance was used in 26% of cases in the Audit. What is most interesting is the very wide variation in the use of PNBs in the hospitals audited [13], ranging from 8% to 92%.

Standard 10 – Neuraxial and general anaesthesia should not be combined

While this technique is frequently used in younger and healthier patients, it is not appropriate except under very select circumstances in the geriatric population. The incidence of hypotension is higher than with either technique alone [13]. The incidence of hypotension overall was very high depending upon the definition. The Audit analyzed hypotension using eight different definitions: fall in systolic blood pressure of greater than 20 or 30%, lowest systolic blood pressure less than 90 or 100 mmHg, fall in mean arterial pressure greater than 20 or 30%, and mean arterial pressure of less than 70 or 55 mmHg.

Using these definitions, the combination of general anesthesia and subarachnoid anesthesia resulted in a prevalence of hypotension of 47–93%. With subarachnoid anesthesia alone, hypotension ranged from 22 to 85% compared to the prevalence rate for all anesthetics that ranged from 32 to 89%. The incidence of hypotension for the general anesthesia group was similar in both magnitude and direction compared to the combined group but it was not quite as severe, ranging from 40 to 92%. These data again reiterate the reasoning behind the preference for subarachnoid over general anesthesia as regards the avoidance of hypotension.

Standard 12 – Patients should be routinely assessed for the occurrence of Bone Cement Implantation Syndrome (BCIS)

The incidence of symptomatology compatible with the diagnosis of BCIS varies across hospitals and across countries [32]. A generally accepted definition of BCIS did not exist prior to this publication by Donaldson et al. [32]. Their definition includes "hypoxia, hypotension or both and an unexpected loss of consciousness occurring around the time of cementation, prosthesis insertion, reduction of the joint or, occasionally, limb tourniquet deflation in a patient undergoing cemented bone surgery" [32]. Their group also proposed a grading system for the severity of the reaction: Grade 1 is characterized by a fall in SpO2 to less than 94% or a fall in systolic blood pressure of 20% or more. Grade 2 is characterized by fall in SpO2 to less than 88% or a fall in systolic blood pressure of 40% or more or an unexpected loss of consciousness. Grade 3 is characterized by cardiovascular collapse requiring CPR [32].

Using these criteria, a separate study from Sweden [33] performed a retrospective analysis in 1016 patients undergoing cemented hemiarthroplasty. The incidence rates of BCIS Grades 1, 2, and 3 were 21%, 5%, and 1.7%, respectively. More importantly, early mortality was related to the severity of the grade. Overall perioperative mortality was 2% which is similar to the range reported in other large studies (1.3–2.5%) [34, 35]. Although there was no difference between the absence of vs. Grade 1 symptoms (5.2% vs. 9.3%, respectively), early mortality with Grade 2 symptoms was 33% and with Grade 3, 88% [33].

However, the role or importance of the syndrome in the long-term outcome of patients is disputed [36, 37]. The primary reason for the dispute is that the functional outcomes for cemented prostheses are felt to be superior to that from the non-cemented version [36, 37]. Thus, many now focus on identifying those patients at highest risk for morbidity and mortality from BCIS as a critical step in improving the safety of hip surgery [38, 39]. Both articles have identified similar risk stratifications regarding BCIS: cardiopulmonary compromise, particularly focused on drugs that suggest compromised cardiac reserve (diuretics, beta-blockers, ACEi); age, frailty was not measured or assessed in these reports; male sex, possibly related to the size of the femoral medullary canal, ASA 3 or 4 status, which is likely a marker for comorbidities; and, finally, hypotension/hypovolemia immediately preceding the insertion of cement.

Providers (geriatricians, anesthesiologists, surgeons) should also discuss with each other plans for managing patients who present with these markers. Clearly discussing the influence each of these risk factors will have on the proposed surgical, anesthetic, and postoperative approach will insure the optimal outcome for each patient. Monitoring hemodynamic status more invasively, while not conclusively shown to change outcome, allows for faster diagnosis and a more tailored therapeutic approach. As the old saying goes, “forewarned is forearmed.”

Monitoring

For most geriatric patients, it seems prudent to place an arterial catheter prior to the initiation of surgery. This serves the purpose of providing beat-to-beat analysis of blood pressure and the ability to rapidly assess the status of arterial blood gases if necessary. Some form of monitoring of cardiac output is also essential to tailoring treatment as most investigators report a drop in cardiac output with the onset of BCIS. The type of cardiac output monitor can take the form of an esophageal Doppler, transesophageal echocardiography, pulmonary artery catheter, or pulse contour devices [40]. Each of these approaches has advantages and disadvantages, but the chief defining characteristic is whether the device can be used in non-intubated, sedated patients (PA catheter and pulse contour devices). Of course, it should go without saying that all standard ASA recommended monitoring is in place prior to initiating the anesthetic.

Treatment

Treatment for BCIS is directed at the primary probable cause of the hemodynamic derangement. While the exact etiology is not clearly defined, a constellation of physiologic alterations result including: an increase in pulmonary vascular resistance, increase in pulmonary artery pressure, decrease in right ventricular function, decrease in cardiac output, decrease in stroke volume, decrease in SpO2, and an increase in V/Q mismatch [38, 39, 41]. While the putative cause of most problems is related to a combination of embolic phenomena of one sort or another (fat, cement, bone, air) and activation of a variety of vasoactive substances (histamine, complement, cytokines, etc.) acting primarily on the right side of the heart [38], treatment is directed at increasing systemic blood pressure, increasing stroke volume and cardiac output.

Preventive volume loading and augmentation of inspired oxygen concentration immediately prior to cementation in high-risk patients combined with monitoring with a CVP or PA catheter is essential to successful management [32]. Management of hypotension can be accomplished with a variety of vasoactive drugs including phenylephrine, norepinephrine, and vasopressin for increasing systemic vascular resistance; epinephrine and dobutamine for increasing cardiac output; and if a pulmonary artery catheter is in place, milrinone could be used for pure right ventricular overload and failure. The latter compound however is a significant vasodilator and should rarely be used in this scenario without evidence of isolated right ventricular overload (high CVP, tricuspid regurgitation or poor right ventricular function, and an under-filled left ventricle as imaged on echocardiography), and even then, it is best used in combination with a vasoconstrictive agent.

Transfusion

The use of blood and blood products has become more controversial over the last decade. Originally, a more liberal (definitions vary but generally means transfusion for hemoglobin concentrations of less than 10 gm/dl) policy was used in the elderly. The prevailing belief was that the higher incidence of comorbidities (primarily cardiovascular and pulmonary) and a desire to rapidly regain functional status required a higher oxygen-carrying capacity [42].

However, in 2011, a large multicenter study (FOCUS – *F*unctional *O*utcomes in *C*ardiovascular Patients *U*ndergoing *S*urgical Hip Fracture Repair) from the NIH strongly suggested that this was not the case [43]. The study was carried out in 2016 patients over the age of 50 with a history of or risk factors for cardiovascular disease and a hemoglobin level of less than 10 gm/dl. Patients were then assigned to either a liberal (threshold of 10 gm/dl) or restrictive (threshold of less than 8 gm/dl) transfusion strategy. The primary outcome was mortality or inability to walk across a room without human assistance on 60-day follow-up. The average age of their participants was approximately 82 years and approximately one-quarter of the participants were male; there were no differences between groups regarding the type or extent of cardiovascular risk factors, type of fracture, type of anesthetic, or primary residence (approximately 88% in both groups were in a retirement home or at home). Likewise, there were no differences in hemoglobin prior to surgery (average of 11.3 ± 1.5) or at entry into the study (9.0 ± 0.8); however, blood loss was slightly and statistically (though not clinically relevant) greater in the restrictive group (209 ± 179 vs. 232 ± 257, respectively).

Fifty-nine percent of patients in the restrictive group did not receive transfusions, while only 3.3% of patients in the liberal group were not transfused. Compared to 54.9% of patients in the liberal group, 16.6% of patients in the restrictive group received 2 or more units of red cells. There was no difference in the age of the units transfused or the use of leukoreduction. The primary reason for transfusion in the restrictive group was tachycardia or hypotension. At 30 days, 46.1% of patients in the liberal group and 48% of patients in the restrictive group met the criteria for the primary endpoint (death or inability to walk), a nonstatistically significant difference. At 60 days, the percentages had decreased (35.2% and 34.7%, respectively), but there remained no statistical difference between the two groups. Mortality rates for these same two time periods were 5.2% and 4.3% for the liberal vs. restrictive groups and 7.6% and 6.6%, respectively.

This same finding was confirmed by at least two further studies [44, 45]. The first trial examined functional outcomes in 305 patients, but did not prospectively group patients by a transfusion strategy, but rather measured their ability to walk in a predetermined amount of time (6 min), maximal hand strength, and two measures (SF36 and CR10) for QoL (Quality of Life) following either hip or knee arthroplasty [44]. Patients were assessed preoperatively and again on postoperative days 1–10 where they completed the SF36 form and were asked to walk as far as possible in 6 min. They were then asked to assess their level of effort during the walk on a CR10 scale [46], and finally their grip strength was measured in their dominant hand. Patients were grouped according to their hemoglobin value on the day of their postoperative visit into four groups: ≤ 8, 8–9, 9–10, and ≥10 gm/dL. There were no differences in the four outcome variables across the four groups except for grip strength as the percentage of males in the ≥10 group was significantly higher (47% vs. 29%, 19%, and 32%, respectively). Most patients were examined postoperatively between days 4 and 5 (4.6 ± 1, 4.5 ± 1.5, 4.8 ± 1.5, and 4.6 ± 1.7 respective to Hgb group). While there were significant decreases over time in each of the groups, they all performed equally well compared to their preoperative states. Further, there were no significant differences between the groups with respect to adverse events (cardiac and respiratory), symptoms of anemia, length of stay, or incidence of prolonged hospital stay.

The second trial involved 603 patients who were prospectively randomized to a restrictive or liberal transfusion strategy [45] and followed for 14 days following operation. Outcome measures included complications (infectious, respiratory, neuropsychiatric, cardiovascular, and hemorrhagic), mobilization delay, QoL (FSI or Functional Status Index), and mortality. Demographic criteria were balanced across groups apart from a history of COPD which was higher in the restrictive group (incidence of 10.7 vs 4.6%). As expected, the number of transfused patients was smaller in the restrictive group (26.4% vs. 39.1%). There was no difference in hospital stay or median blood loss between groups. Infectious and respiratory complications occurred more frequently in transfused patients regardless of categorical assignment. Of those patients who developed infections, 66% had been transfused, while 70% of patients with respiratory complications were transfused. QoL scores were not affected by transfusion strategy.

Although these studies would appear to conclude the debate about where transfusion triggers should be set, a Danish study was published in 2016 that has reignited the debate [47]. This paper is a composite of three papers published as part of a thesis for PhD [48–50]. The three papers sought to examine the role that frailty and not simply age plays in responding to transfusion strategy following surgery for hip fracture in 284 patients.

The patients were drawn from two populations: one in nursing homes and the other in sheltered living facilities. The two groups were matched across a wide variety of demographic factors including but not limited to ADLs, gender, residence, comorbidity, dementia, age, and pre- and intraoperative transfusion. The only statistically significant difference was in age which was not clinically significant (85.7 vs. 86.9 for restrictive vs. liberal, respectively). The restrictive group was transfused at a level of 9.7 gm/dL and the liberal group at 11.3 gm/dL. This is an important distinction from almost all the other studies we have discussed. The restrictive group is being transfused at a level that would generally be "liberal" in almost all the other studies.

Thus, the first significant question to ask is to what degree are the results reflective of a comparison of essentially two different liberal transfusion strategies? Essentially, they created "more" and "less" liberal transfusion groups with a relatively small number of patients. They did find that their frailest patients were from nursing homes (interestingly, however, the incidence of dementia was not different between the two residency groups) and that these patients had the higher survival rate in the more liberal group (36% vs. 20% at 90 days). Further, 30-day mortality was significantly lower in all patients in the more liberal group (7% vs. 16%). There is a caveat to these findings, however, as they evaluated their outcomes with respect to both an intention to treat and on a per protocol basis.

The per protocol group was smaller than the intention to treat group with only 260 patients in total. While the 90-day mortality was higher in the restrictive group in both analyses, the 30-day mortality for all patients was only significantly different in the per protocol analysis. Also, they did not find an increase in infections with the more liberal group which other investigators have noticed. Overall, the most important findings from this study is the outcomes as related to frailty rather than simply age. Unfortunately, the use of relatively high values for the "restrictive" group made the ability to relate this study to so many others in the literature very difficult.

Thus, one is left with the impression that unless the patient has pre-existing coronary artery or severe pulmonary disease, the restrictive strategy appears to be as safe as the more liberal strategy. Further, if one lives or works in an environment where blood and blood products are expensive or difficult to locate, then the restrictive strategy can conserve these previous resources at no physiologic expense to the patient.

Total Knee Arthroplasty

Unlike total hip arthroplasty, there are few guidelines that suggest best practices. There are, however, ERAS pathways that are quite helpful in identifying areas on which one should pay attention. Almost all the ERAS protocols focus on alterations in behavioral, pharmacological, and procedural issues [51]. An example of a behavioral change is the education of both patient and staff about the principles of ERAS, while an example of pharmacological change is the addition of gabapentin on the evening prior to surgery and the use of tranexamic acid and IV acetaminophen prior to induction. An example of a procedural change is the removal of discharge from the surgeon's purview and instead being discharged when standardized criteria are met.

The development of ERAS pathways occurred much earlier outside the United States; thus, the larger trials and outcome measures are from outside the United States [51–54]. In the first of these papers [51], the ERAS pathway was introduced in 2008. The initial pathway included oral gabapentin 300 mg on the evening prior to surgery along with dexamethasone 10 mg. At the induction of anesthesia, an additional 4 mg of dexamethasone is administered. The preferred anesthetic technique was either low-dose subarachnoid anesthesia (2–3 ml of 0.25% plain or 2 ml of 0.5% heavy bupivacaine with no additional intrathecal opioids) or a propofol-based anesthetic with ketamine added as a single dose of 0.5 mg/kg. Acetaminophen is added with both techniques, and a Cox-2 inhibitor can be added. While there is no set fluid administration, a more restrictive protocol is encouraged with vasopressors as needed for blood pressure support. Tranexamic acid is administered on induction in a dose of 15 mg/kg but is withheld if there is a history of thromboembolism in the past 6 months.

Local anesthetic (levobupivacaine 0.125% is used in this pathway, but ropivacaine could be substituted) is injected into the joint capsule, muscle, fat, and skin in a total dose of 80 ml. A catheter like the one used for epidurals is placed in the joint exiting away from the incision, and a second dose of 20 ml is added following closure of the wound. The catheter is removed on the morning of the first postoperative day; however, prior to removal, three more 40 ml doses are administered at roughly 6–8 h intervals. Postoperative analgesia also includes gabapentin, 300 mg twice a day for 5 days and oxycodone as needed twice daily for 2 days followed by tramadol 50–100 mg, every 4–6 h. Patients are first mobilized 3–5 h postoperatively, and once the patient can walk with the assistance of external aids, the process for discharge begins. Once discharged, pain is managed with acetaminophen, weak opioids, and NSAIDs.

Using this protocol, 1500 hip and knee patients were compared to 3000 patients using a traditional pathway for the 4 years prior (2004–2008). There were minor differences in demographics with the ERAS group having a significantly higher incidence of hypertension, noninsulin-dependent diabetes, and COPD. There was a significant reduction in both 30- and 90-day mortality (0.5% vs. 0.1%, and 0.8% vs. 0.2%; traditional vs. ERAS). There were no differences in complications between the two groups, and overall length of stay (LOS) decreased from a mean of 8.5–4.8 days and a median of 6–3 days. Unfortunately, TKA was not differentiated from THA in this evaluation; however, it seems unlikely that there would be major differences in mortality between the two surgical groups (THA vs. TKA). This same cohort of 4500 patients was followed for an additional 2 years, and the significant difference in mortality between the two groups was maintained at both 1 and 2 years (2.1% vs. 1.3% and 3.8% vs. 2.7% for traditional vs. ERAS) [54].

The use of regional anesthesia in preference to general anesthesia is in keeping with what was already discussed in the THA section. Further, others have noted that subarachnoid anesthesia in elderly patients undergoing TKA is associated with improved outcomes, including lower incidence of delirium and sore throat and lower pain scores on postoperative days 3 and 4 [55]. Timing of antiplatelet inhibitors prior to and after surgery needs to be considered before neuraxial puncture. Although aspirin alone is considered safe in neuraxial anesthesia, the concurrent administration of other antithrombotic drugs significantly increases the risk of spinal hematoma, and the recommended safety times for each of these other drugs must be strictly followed [56].

Both remaining large comparisons are from the regions of Australia and New Zealand [52, 53], and again they both examine a combination of THA and TKA. The first study was completed in 2013 and their study enrollment was divided into three phases: a traditional phase from March to September of 2012, a training phase during September of 2012, and the ERAS pathway from October of 2012 to May of 2013 [53]. Total patient enrollment was 709 with 412 enlisted in phase 1 and 297 in phase 3. A patient was considered to have successfully completed the ERAS pathway if 11 or 16 predetermined criteria were met including coordinator counseling preadmission, preadmission review by a physiotherapist, clear oral fluids up to 2 h preoperatively, preoperative oral carb loading, no sedative premedication, subarachnoid anesthesia, local anesthesia (this could be either local infiltration or femoral (or adductor canal) nerve block – we will discuss which PNBs are most beneficial at the end of this section), less than 10 mg of IV morphine, fluid restriction to less than 1 L after accounting for blood loss, active intraoperative warming, antiemetic prophylaxis, multimodal oral analgesia through the 3rd postoperative day, oral carbohydrate supplementation in the PACU, mobilization within 24 h, and hospital discharge within 5 days.

As one can see, these are almost identical to the criteria used in the study discussed previously. Demographic data did not differ significantly between phases 1 and 3 with the exception of the rate of NSAID/COX-2 inhibitors' use preoperatively (26% vs. 37%, respectively). Overall implementation of the pathway was extremely good at 81%. Further, there was a significant reduction in the length of hospital stay (geometric mean of 5.3 (1.6) vs. 4.5 (1.5), phase 1 vs. phase 3) and a higher percentage of patients were discharged by day 5 (52% vs. 60%, phase 1 vs. phase 3). Like the previous study, local infiltration was the preferred method of local analgesia compared to PNBs (75% vs. 15%). Despite this, dynamic pain scores (with movement) were significantly better in phase 3 compared to phase 1 in PACU (0 (0–4) vs. 0 (0–7), median (IQR)) and at 24 h (mean knee flexion in degrees – 57 (24) vs. 51 [18], phase 3 to phase 1). There was also significant improvement in time to weight bearing, oral food and fluid intake, and removal of drainage and urinary tubes. Six-week complication rates were similar as was the rate of hospital readmission while patient satisfaction was higher. Fifty-nine percent of patients in the ERAS pathway were considered ready for discharge on day 3 vs. 41% of those in standard practice.

In the final assessment of ERAS, the traditional group was historical (June through August of 2012) and was compared to a prospective ERAS group (August through December of 2013). The ERAS pathway was like those described previously in all respects with a few exceptions. There was more attention to postoperative nausea and vomiting prophylaxis (ondansetron 4–8 mg around the clock for the first 24 h) and lesser reliance on PNBs and local infiltration for postoperative analgesia; 100 patients were included in both groups for analysis.

There were no differences between the two groups with respect to demographic criteria. The median LOS in the ERAS group was decreased by 1 day compared to traditional (4 vs 5 days). Complication rates did not differ between the two groups nor did overall mortality. There was a small but statistically significant reduction in overall costs associated with the ERAS pathway. Finally, 81% of patients in the ERAS pathway met their early mobility goals versus only 48% of the traditional group. Further, 82% of those in the ERAS pathway who met early mobility goals were discharged in 4 days or less. Readmission rates for both groups were similar.

In summary, the use of ERAS pathways that include most, if not all, of the approaches described here result in an improved outcome regarding mortality, LOS, and costs. Overall, there seems little reason not to adopt these strategies moving forward. The care of an aging population of orthopedic patients must be focused on providing the highest quality care for the least amount of fiscal resources to avoid either rationing of care or excessive medical (and ultimately societal) expenditures.

Peripheral Nerve Blockade

As noted, many (but not all) of the ERAS pathways suggest use of PNBs to reduce the need for intraoperative analgesia and anesthesia (if general anesthesia is used) or to enhance the postoperative analgesic management and reduce the reliance on opioids. The innervation of the skin around the knee and surrounding tissue comes from the femoral nerve, obturator nerve, and sciatic nerve (the last as two branches – the tibial and common peroneal nerves). The joint space is innervated by the femoral nerve anteriorly and the obturator and sciatic nerves posteriorly.

A very recent paper [57] has examined the use of a variety of different approaches for providing postoperative analgesia including PNBs, periarticular infiltration, and epidural analgesia. The authors identified 170 trials published between 1987 and 2016, encompassing over 12,500 patients and utilizing 17 different treatment modalities. They evaluated these modalities for three primary outcomes: acute postoperative pain during rest and movement, postoperative opioid consumption, and quality of early postoperative rehabilitation (range of motion combined with degree of flexion). Secondary outcomes included postoperative incidence of nausea, vomiting, pruritus, urinary retention, and DVT, LOS, and blood loss.

Approximately 59% of the trials (121) used some version of neuraxial anesthesia, but the clear majority of these (87 of 121) used only subarachnoid anesthesia. Of the 170 trials, 57 used general anesthesia (7 TIVA and the remainder volatile with 16 of the latter including N_2O). Seventy-one of the trials used acetaminophen with or without NSAIDs, while 9.4% used some form of gabapentin, and 24 trials (~14%) did not specify.

All forms of combined PNBs were superior to any single nerve block for analgesia. The cumulative ranking curves were different based on the primary outcome examined. The top five methods of analgesia for each primary outcome were summarized over the first 72 h: *pain at rest*, femoral/obturator, femoral/sciatic/obturator, lumbar plexus/sciatic, femoral/sciatic, and the fascia iliaca compartment block; *range of motion*, femoral/sciatic, femoral/obturator, femoral, lumbar plexus, and periarticular infiltration; *reduction in opioid consumption*, femoral/sciatic/obturator, femoral/obturator, lumbar plexus/sciatic, lumbar plexus, and femoral/sciatic; and *pain with movement*, femoral/obturator, intrathecal morphine, femoral/sciatic, periarticular infiltration, and lumbar plexus/sciatic.

Secondary outcomes showed similarly disparate results depending upon the outcome examined. The *incidence of nausea* was lowest with auricular acupuncture followed by femoral/obturator, lumbar plexus/sciatic, femoral/sciatic, and adductor canal block. The *incidence of vomiting* on the other hand was lowest with liposomal bupivacaine followed by femoral/obturator, periarticular infiltration, femoral, and femoral/sciatic. *Pruritus* was lowest with the lumbar plexus/sciatic block followed by auricular acupuncture, femoral, femoral/sciatic, and periarticular infiltration. Finally, the *incidence of urinary retention* was lowest with auricular acupuncture followed by lumbar plexus, lumbar plexus/sciatic, femoral/sciatic, and femoral. *Length of stay* was shortest with the adductor canal block followed by lumbar plexus/sciatic, periarticular infiltration, liposomal bupivacaine, and placebo. Finally, the *incidence of deep venous thrombosis* was lowest with femoral/sciatic blocks followed by placebo, epidural anesthesia, adductor canal block, and periarticular infiltration.

Perhaps the most interesting finding in this meta-analysis is the fact that auricular acupuncture placed in the top two in three of the six secondary outcomes measures. In fact, it was the top performer in two categories, lowest incidence of nausea and urinary retention, and was second in pruritus. The only PNB that placed consistently in the top five was the femoral/sciatic, placing in five of the six secondary outcomes. The lumbar plexus/sciatic was a close second placing in the top five in four of six secondary outcomes as did periarticular infiltration.

The authors conclude by stating that the combination of femoral and sciatic PNBs appears to be the best choice overall, a finding that certainly makes sense when applied to the neural anatomy of the knee and knee joint. The addition of the obturator nerve to this block combination improves analgesia and opioid consumption but cannot supplant either block. The need for participation in rehabilitation immediately following or in proximity to surgery has altered the anesthetic landscape for TKA significantly. While epidural anesthesia was considered the gold standard, the need to preserve quadriceps function has significantly impaired the analgesia available from the block. This is due to the reduction in the local anesthetic component to a point where ineffectual analgesia results. The preservation of quadriceps function is also the likely reason for an increase in the use of the adductor canal block which is like a femoral block for pain control and opioid consumption but superior for length of stay (ranking first). Clearly, more work is needed to help define the role of PNBs in analgesia during rehabilitation.

Finally, while it may be tempting to suggest that the use of PNBs can help reduce the need for postoperative opioid use and thus the likelihood for chronic opiate abuse and misuse, a recent paper has cast doubt on this supposition [58]. Prolonged use of opioids after TKA occurs in 10–34% of patients [59]. In this paper, the authors examined slightly over 120,000 patient records from the years 2002–2012 and used billing data to identify the use of PNBs or neuraxial blocks in patients aged 65 or less. Chronic opioid use was defined as having filled ≥10 prescriptions or ≥120 days' supply of opioid in the first year after surgery (excluding the first 90 days). They used a multivariable logistic regression and adjusted for a large set of possible confounding variables (i.e., comorbidities, previous opioid use, alternative medication use, etc.). They found no association between peripheral nerve blocks in any of their three subgroups (opioid naive, intermittent opioid users, and chronic opioid users) and the chronic use of opioids after surgery.

There are however at least two major problems with this study. The first is that apropos of our previous discussion on the best approach for analgesia for TKA, there was no use of sciatic blocks in this study. Most of the patients received femoral blocks only (88.6% of patients) while much smaller numbers received either a lumbar plexus block (0.55%) or other types of blocks (3.61%). This suggests that analgesia in the early postoperative period was incomplete and may have contributed to the outcome. However, since the neuraxial group also demonstrated no relationship to chronic opioid use, this explanation seems less likely. The unadjusted incidence of chronic opioid use in the first year postoperatively was 1.78% vs. 1.81% (block vs. no block) in the naive group;

6.08% vs. 6.15% (block vs. no block) in the intermittent group, and 67.6% vs. 67.8% (block vs. no block) in the chronic group.

Thus, one is left with the finding that while the use of PNBs is clearly helpful in managing pain and reducing opioid consumption in the acute postsurgical period, there is minimal data supporting the ability of the PNBs to reduce the chronic use of opioids post surgery.

Spine Surgery

Cervical

Cervical spine surgery is most easily discussed along two main categories: emergent and elective. Elective surgical procedures include decompressive, disc, and stabilization procedures and are generally required for treatment of cervical myelopathy as the result of degenerative changes in the spine that occur and increase with age [60], and age is often considered a risk factor for pursuing surgery [61, 62]. This concern regarding age translates into different surgical approaches and associated comorbidities. For example, anterior approaches are generally favored over posterior in the geriatric age group and more levels are decompressed at the time of surgery compared to a younger cohort [63]. Meanwhile, ERAS has not been a significant factor in managing patients' surgical journey, even though these procedures offer many of the opportunities to improve LOS and rate of rehabilitation from which other surgical procedures have benefited [63].

In a recent meta-analysis [64] of 2868 patients across 18 studies, the authors found a lower functional recovery rate in an elderly (age greater than 65) group of patients (a finding that led many to suggest that advanced age results in worse outcomes); however, these same patients generally noted that the recovery was sufficient to reduce their dependence and improve their quality of life. This meta-analysis suggests that age is only a functional risk factor and that patient-derived outcomes are more important than purely objective measures of functional recovery. The Swedish Spine Register has been ongoing since 1993 [65] and they report both surgical outcomes and patient-reported outcomes. They noted that the older patients were generally more satisfied with their experience than their younger counterparts. For those 65 and older, 92–93% of patients were satisfied with the treatment of their pain and discomfort vs. 84–89% of those between the ages of 16 and 64 [64].

There are other differences due to age and comorbidities. The LOS for elderly patients is generally prolonged; however, blood loss is generally less than that in their younger counterparts [63]. The most commonly reported complications and adverse events following surgery across all age groups were C-5 palsy, CSF leak, pneumonia, and delirium [63]. However, only delirium was statistically significantly different (higher) in the elderly age group. Thus, future focus for ERAS pathway development should include management of delirium as a principal component in addition to the usual components previously discussed. In a very recent analysis of outcomes in 10,232 patients aged 80–103 years [66], not only was LOS longer (3.62 vs 3.11 days), but also the incidence of in-hospital complications (11.3 vs. 7.15%), the rate of nonroutine discharge (33.7 vs. 16.2%), and in-hospital mortality were all higher (0.31 vs 0.06%) in the elderly population.

Emergent cervical surgery in the geriatric age group is primarily two procedures: Type II odontoid fractures [67] and central cord syndrome [68]. Type II odontoid fractures are the most common cervical spine fracture in patients over the age of 65 [66]. In their systematic review of the treatment of these fractures, the authors identified 21 articles covering 1233 patients [66]. Overall, both short- (≤ 3 months) and long-term (≥ 12 months) mortalities were lower (odds ratio, 0.43 {0.3–0.63} and 0.47 {0.34–0.64}) with operative intervention compared to non-operative treatment. Further, there was no difference noticed regarding complications (1.01 {0.63–1.63}). Also, unlike the elective management of cervical myelopathy, there was a roughly even distribution between anterior and posterior approaches with no differences noticed regarding mortality (short- or long-term) or complications. Unfortunately, there were significant limitations to their study; most importantly, they had no way to adjust for selection bias, as individual comorbidities were not reported in most of the studies.

Central cord syndrome typically occurs in patients with pre-existing cervical spondylosis who are then exposed to a hyperextension injury and is the most common incomplete spinal cord injury [67]. In their review of national trends in the management of central cord syndrome, the authors assessed outcomes for 16,134 patients from 2003 to 2010. Overall, approximately 40% of patients were treated using a surgical approach; however, the rate of surgery was lower in those aged 65–79 (27.4%) and over 80 (7.8%). Mortality however was significantly associated with older age with those patients over the age of 79 comprising 34.8% of those experiencing mortality. Mortality was also associated with several comorbidities including congestive heart failure, weight loss, coagulation disorders, and diabetes mellitus [67].

Anesthetic Approach

One might surmise that general anesthesia with endotracheal intubation is the only approach for cervical surgery; however, there are in fact both regional and non-intubating approaches for surgery [69, 70]. We will review these two options first and then discuss approaches for general anesthesia.

The use of deep and superficial cervical plexus blocks (CPB) for anterior cervical discectomy and fusion (ACDF) surgery was investigated by a group from China [68]. They compared general anesthesia (GA) to CPB in 356 patients undergoing single-level ACDF and compared several characteristics including but not limited to preparation/induction time, hemodynamic changes, duration of surgery and recovery time, blood loss, and patient satisfaction. As might be anticipated, induction and recovery times were significantly shorter in the CPB group. Interestingly, the duration of surgery was also significantly shorter (though a clinically insignificant 4 mins) in the CPB group. Blood loss was identical between groups; but hemodynamic responses were less dramatic with the GA group. Analgesic need and treatment for PONV were significantly reduced in the CPB group, and the incidence of severe PONV was significantly higher in the GA group. Patient satisfaction was significantly worse in the CPB group with 29 of 187 (15.5%) patients saying that they would NOT select this technique again in the future compared to only 2 of 169 (1.2%) patients in the GA group. Finally, three patients developed cervical nerve palsy and two developed Horner's syndrome in the CPB group.

Interestingly, we could not identify any trials of the use of Laryngeal Mask Airway (LMA) in anterior cervical surgery; however, there is a report of their use in posterior cervical surgery [69]. This Danish study compared two groups: self-positioning prone prior to surgery and introduction of an LMA following induction of anesthesia vs. standard general endotracheal intubation (GETA), followed by positioning in the prone position. However, most importantly, the exclusion criteria for the study included BMI greater than 35 kg/m^2, a Mallampati score of 3 or 4, surgical time of 2 h or more, and age greater than 70. This, to us, seems critical to the interpretation of the outcomes as those patients most likely to suffer from positioning and airway complications as well as almost all geriatric patients were excluded at the outset. One hundred forty patients were randomized and 131 patients were evaluated regarding time to readiness for X-ray, airway problems, sore throat, hoarseness, and myalgia/arthralgia. The LMA was designated as "correctly seated" once a gastric tube was in place and the seal was complete (three attempts were allowed before changing to GETA). No succinylcholine was used for placement of the endotracheal tube. Only two patients required conversion from LMA to GETA secondary to incomplete seal, and a third patient was canceled due to severe hypotension. There were no differences between the groups regarding duration of surgery, emergence, and LOS in PACU. There were slightly more patients with myalgia/arthralgia in the GETA group at 3 h, but these differences resolved prior to the 24-h analysis. Overall, it seems that this technique cannot be recommended for routine use in the United States.

No discussion regarding anesthesia for cervical spine surgery in the elderly would be complete without consideration of the use and type of intraoperative neurophysiologic monitoring. We have elected to combine these two discussions as one has important effects on the other.

Most authors agree that the use of intravascular arterial assessment is important in avoiding or treating episodes of hypotension. While both the spinal cord and the brain autoregulate, this is complicated and altered by the presence of hypertension, diabetes, and anesthetics [71, 72] in addition to the normal carbon dioxide and sympathetic influences. Further, if one is using motor evoked potential (MEP) monitoring, significant hypotension can alter MEP recordings; thus, the use of invasive monitoring for arterial blood pressure is crucial [73].

The choice of anesthetic can also be affected by the presence of MEP recording. The use of intravenous agents is broadly considered to be superior to inhalational agents including nitrous oxide [72, 74, 75]. However, inhalational agents have been used successfully with the admonition that the total dose be kept at or below 0.5 MAC [76]. Perhaps the most important aspect of anesthetic management is to maintain a stable anesthetic background on which the intraoperative monitoring is used. If MEPs are not contemplated or needed, there seems to be little reason to prefer one technique over another. Other patient-related aspects that can make for a difficult monitoring environment include both age and BMI [74].

In a recent single-site report regarding the usefulness of monitoring for cervical spine surgery [77], a group of investigators from the United States identified 200 patients' charts retrospectively to assess the effect of neuromonitoring in cervical surgery. Anterior (114), posterior [73], and combined [12] surgical approaches were used, and the average age was NOT in the geriatric age group (50.1 ± 13.7 for anterior, 55.2 ± 13.4 for posterior, and 54.8 ± 13.7 for combined). Both SSEP and MEP were utilized in the study and a total of eight neurological alerts were detected. Three patients (2.6%) had SSEP alerts, two were related to arm malposition and one to hypotension. Five patients (4.4%) had MEP alerts, four by significant hypotension and one by bone graft compression. All were in the anterior approach group. Overall sensitivity for SSEP alone was 37.5% and for MEP alone, 62.5%; however, the sensitivity and specificity of the combination of the two modalities was 100%. The mean reduction in mean arterial pressure (MAP) at the time of alteration in the signal was 33.7%. Restoration of MAP restored normal signals within 5 min.

After considerations for intraoperative monitoring and positioning, the next most likely time for problems to occur is during airway management with different types of problems occurring at intubation and extubation [78, 79]. In their most recent review of closed claims regarding cervical spinal cord, root, and bony spine injuries, Hindman et al. noted that 54% of all cervical injury claims (26 of 48 patients) were related to cervical spine surgery [77]. Fully 96% of the patients were intubated under direct vision with fiber-optic intubation being rare. The authors concluded that,

"However, almost equally often, one or more nonsurgical factors may unfavorably affect the cervical cord, particularly in susceptible patients (pre-existing deficits). These factors appear to include head/neck position during surgery or intubation, and/or arterial blood pressure…"

Interestingly, in another review from one of the author's institutions [80], the overall incidence of new postoperative deficits was 2.4% while the incidence of SSEP changes was over twice that at 5.3% (27 patients). While the authors noted that the most common identifiable cause of SSEP changes was hypotension (11 patients), changes related to the surgical process (vertebral body decompression, disc distraction, retractor position, durotomy, graft dislodgement) were the leading cause of SSEP changes (13 patients). Patient positioning was responsible for SSEP changes in two patients, one related to head positioning and one related to taping of the arm. Although intubation has not been routinely associated with involvement with cervical injury, the possibility clearly exists and thus it seems a prudent approach to use some form of indirect visualization for intubation [81].

The postoperative airway issues principally involve laryngotracheal and laryngopharyngeal edema formation [78]. In a recent review article on this topic, several important facts emerge. First, the overall incidence ranges in the literature from 1.2% to 6.1% with the incidence increasing with increasing degrees of surgical intervention (multiple levels or combined anterior/posterior approaches) [82]. The etiology of airway compromise ranges widely from edema formation secondary to prolonged retraction to hematoma formation, abscess development, and construct failure. Risk factors for the development of airway issues include exposure of more than three vertebral bodies, exposures involving C2–C4 levels, blood loss over 300 ml, surgical time greater than 5 h, pre-existing myelopathy, and patients undergoing combined procedures [81].

There is no proven deterrent to the onset of airway compromise; however, there is a suggested risk stratification system that sounds rational and divides patients into three tiers: low, intermediate, and high risk [78]. Low- and intermediate-risk procedures without complicating patient factors (morbid obesity, OSA, etc.) such as one- or two-level decompression and reconstruction or a three-level discectomy and fusion can be extubated safely in the operating room. However, the intermediate group may require overnight monitoring to insure there are no delayed sequelae. The high-risk group which is constituted by complex repairs or combined approaches paired with difficult patient characteristics suggests the need for delayed extubation in the ICU for up to 36 h [81]. Following extubation, the patient should remain under close observation in the ICU for 4–6 h prior to transfer.

While the use of dexamethasone was originally suggested to prevent the onset of edema formation, one current prospective, randomized trial has failed to find an effect [83]. There were 66 patients in total and they received three doses of dexamethasone, 20 mg prior to incision and two doses of 10 mg each at 8 and 16 h later. The patients were all in the high- to intermediate-risk categories and as such were left intubated until the day following surgery, and this is likely why these investigators did not find a difference. Had they extubated these patients immediately after surgery, we suspect they may have found a difference. They did notice that there was a significantly higher fraction of females in those patients who had delayed extubation (11 patients were delayed in extubation and of whom 8 were female). There were no other significant differences except that those patients who had delayed extubation were kept in the hospital 1.5 days longer (4.27 vs. 5.63 days). Thus, while this trial on the surface appears to be negative for dexamethasone, the purposeful delay in extubation of 1 day may have obscured any true difference. It is also possible, however, that there are two separate mechanisms for airway compromise postoperatively: an early component related to physical trauma that is responsive to steroid therapy and a later component related to surgical inflammation that is less responsive.

Two further trials have been conducted regarding the use of steroids for anterior cervical spine surgery (ACDF). The first article examined the use of morcellized collagen sponge mixed with triamcinolone and applied to the retropharyngeal space prior to wound closure in 25 patients undergoing ACDF for 1 or 2 levels and compared them to 25 patients who did not [84]. Instead of assessing the incidence of significant airway issues, they measured the amount of prevertebral soft tissue swelling (PSTS) and the incidence of odynophagia. The PSTS ratios of the steroid vs. that of the control group were compared immediately, at 48 h, 4 days, and 2 weeks postoperatively. Those ratios were 58.2 vs. 74.3%, 57.9 vs. 84.1%, 56.3 vs. 82.9%, and 44.9 vs. 51.4%; all differences were statistically significant at all time periods. The incidence of odynophagia was also lower in the steroid group.

In the second study, 112 patients undergoing multilevel ACDF received either dexamethasone at a dose of 0.2 mg/kg at induction followed by four doses of 0.06 mg/kg at 6 h intervals vs. saline. Swallowing function was not assessed formally until 1 month following surgery [85]. Patients who became symptomatic with severe dysphagia or airway problems were given steroids for therapy. Evaluations were carried out both with and without these patients included in the analysis. Dysphagia was significantly reduced in the postoperative period for up to 1 month as were LOS and airway difficulty. Seven of the 56 patients in the placebo group required steroids for dysphagia compared to only one of 56 in the steroid group. While airway compromise and need for intubation did not reach significance, it was extremely close ($p = 0.057$). Overall, there was 2.7% incidence of airway difficulty and three of the patients in the placebo group required intubation and further treatment with steroids compared to none in the steroid pretreated group. Although not related to this discussion, they also noted that the use of steroids delayed but did not decrease the incidence of successful fusion.

The management of postoperative pain has been addressed by several groups [86–89]. There is no protocol that is universally accepted across institutions, thus various approaches have been tried with good success. Both local anesthetics and infusion-based techniques have been used with good success. If the only parameter measured was reduction in opiate consumption in the postoperative period, then the intravenous techniques using either dexmedetomidine or low-dose ketamine seem preferable to the use of either liposomal bupivacaine or superficial cervical plexus block. The dose of dexmedetomidine used in the postoperative period (after use in the intraoperative period as well) was 0.2 mcg/kg/hr for the first 24 h, while the dose of ketamine was 1 mg/kg at induction followed by an infusion of 83 mcg/kg/hr for the first 24 h. Both groups noted significant reductions in the use of PCA opiates as well as improved patient satisfaction.

Finally, while there are no true ERAS pathways or guidelines for the management of anterior cervical spine surgery (ACSS) per se, there is a recent publication that has suggested best practices [90]. These recommendations are the product of a panel of five neurosurgeons, three anesthesiologists, one orthopedic spine surgeon, and a registered nurse. Further, the consensus statements are intended to be used for ambulatory ACDF (discharge within 4–8 h of admission). The panelists grouped all statements into five broad categories: patient selection, postoperative nausea and vomiting, pain management, surgery and discharge preparedness, and provider economics. The only patients that were to be excluded were those with severe cardiopulmonary comorbidities (ASA Grade 4 and above and NYHA Grade 3–4). Risk for PONV should be assessed prior to surgery and prophylaxis agents should be tailored. Interventions structured to reduce PONV include the use of nonopioid analgesia, aggressive hydration, dexamethasone or 5-HT3 antagonists, oral famotidine on arrival, and transdermal scopolamine for those patients with a history of motion sickness. Consensus was also reached for the development of an analgesic plan prior to surgery. Intravenous methocarbamol (Robaxin), if available, should be considered for us intraoperatively. Non-opioid analgesics such as acetaminophen instead of nonsteroidal analgesics and opiates should be considered as first-line agents and titrated against a validated pain scale postoperatively. Patients and caregivers must be educated on all aspects of the procedure to include: aims of surgery, procedural details, and anesthetic-related issues. This should also include expectation with respect to postoperative care including smoking cessation (preferably 6 weeks prior to surgery), medication use, warning signs, and access to emergency care as well as an evaluation for thromboembolic risk. This preparation should also include counseling for those patients with low pain threshold or taking opiates chronically. Finally, all agreed that patients and caregivers should be made aware of the risk for hematoma/edema formation and recognize the signs of impending issues. All panelists also agreed that patients should be observed for at least 3 h post surgery as well as receiving a call from a nurse on the morning following surgery.

While none of these suggestions meet the standards required of an ERAS pathway or surgical guidelines, these are sensible suggestions if one is to move the use of ACSS surgery into the ambulatory arena.

Lumbar

Background

The United States has the highest rate of lumbar spine surgery in the world despite a similar incidence and prevalence of spine disorders worldwide, with large regional variations across the United States [91]. In 2007, *Consumer Reports* rated lumbar spinal surgery as number one on its list of overused tests and treatments [92], and questions have been raised about the appropriateness of surgical indications [93]. The population over the age of 65 is the fastest growing segment in the United States, and the need for spinal care is expected to rise further. The main concerns for geriatric patients undergoing lumbar spine surgery are (1) limited functional and cognitive reserve even in the absence of disease (the "healthy" elderly patient), (2) high likelihood of age-related comorbid conditions which may increase complications associated with invasive procedures, and (3) poor bone quality predisposing to fractures and spinal deformity which may lead to both repeat and more invasive procedures.

The Aging Spine

Physiologic changes associated with aging can affect all bony structures, articular facets joints, and intervertebral discs ultimately resulting in a stiffer yet weaker spine [94]. A number of degenerative diseases are prevalent in the elderly population. *Spinal stenosis* is a narrowing of the spinal canal leading to back and radicular pain, with neurogenic claudication being the classic presenting feature. Imaging studies do not correlate well with symptoms in elderly people, so diagnosis of spinal stenosis is based on the clinical syndrome.

Spondylolisthesis is any displacement of the cephalad vertebral body in relation to the caudal vertebral body and posterior elements. Spondylolisthesis occurs most frequently at the L4–L5 levels and is usually accompanied by spinal stenosis at the corresponding vertebral level. *Vertebral fractures* may occur due to endocrine and metabolic changes associated with aging leading to osteoporosis and poor bone quality.

Geriatric Spine Surgery: Efficacy and Safety

Non-operative treatments are usually the first line of treatment unless the patient presents with acute neurologic deficits or worsening symptoms such as intractable pain. There is considerable controversy regarding the benefits of surgery compared to nonsurgical interventions for spine disorders, and the main culprit may be the lack of agreement between spine surgeons as to the best surgical treatment modality for various degenerative lumbar diseases. In a retrospective cohort analysis of Medicare recipients [95] undergoing surgery for lumbar stenosis between 2002 and 2007, the rate of complex fusion procedures increased 15-fold, from 1.3 to 19.9 per 100,000 beneficiaries despite the overall decline in surgical rates over that time period. More complex procedures were associated with increased risk of major complications, 30-day mortality, and resource use. The study could not clearly answer why more complex operations were performed as it seems very implausible that the number of patients with complex spinal pathology increased 15-fold in just 6 years.

Literature on geriatric clinical outcomes is generally poor due to lack of uniformity of basic definitions, absence of standards of care or standardized outcome measures, and small sample sizes. In a review of randomized control studies comparing lumbar fusion surgery to non-operative care for treatment of chronic back pain, Mirza and Deyo could not identify a clear advantage of surgery while stating that limitations of the trials prevented firm conclusions [96]. The Spine Patient Outcome Research Trial (SPORT) is a large, randomized multicenter trial which has examined surgical versus conservative therapy for three lumbar disorders: disk herniation [97], degenerative spondylolisthesis [98], and spinal stenosis [99]. While the trial did not look specifically at geriatric patients, the mean age of the participants in the degenerative spondylolisthesis study was 66 years. The authors reported that surgery was significantly superior to conservative treatment in pain reduction and functional improvement at 2-year and 4-year follow-up. A significant limitation of this study (like many other surgical trials) was the marked degree of nonadherence to randomized treatment (up to 40% crossover from conservative to surgical therapy) which reduced the power of the intention-to-treat analysis to demonstrate a treatment effect. Similar results and limitations were observed for the spinal stenosis (mean age of participants was 65.5) and disk herniation (mean age 42.3) cohorts of the trial with the differences between the groups diminishing over time.

Intraoperative Management

Spinal surgery includes a wide variety of procedures ranging from minimally invasive surgery such as micro discectomy to complex fusion surgery. Perhaps the most important consideration guiding management of the geriatric patients is understanding the invasiveness of the procedure as this can be associated with prolonged operative time in prone position, increased blood loss, and significant postoperative pain impeding functional recovery.

Choice of Anesthesia

General anesthesia is by far the most commonly used technique for lumbar spine surgery. Regional and neuraxial (spinal or epidural) anesthesia are increasingly being favored for other orthopedic procedures like hip or knee arthroplasty and may be associated with superior perioperative outcomes [100]. However, these potential benefits have to be weighed against significant drawbacks during lumbar spine surgery: inability to control the airway in prone position, titrate the duration of the anesthetic, or perform intraoperative neurophysiologic monitoring. Limiting the sedation level (presumably by choosing regional instead of general anesthesia) may offer additional potential benefits in the geriatric population such as decreased incidence of delirium [101] and postoperative cognitive dysfunction. A recent review of 11 studies that compared lumbar spine surgery patients receiving general versus regional anesthesia [102] found no evidence to suggest that morbidity, mortality, or long-term complication rates differ between the two approaches; secondary outcomes such as hemodynamic profiles and analgesic requirements appeared more favorable in the regional group. Ultimately, the anesthetic choice should be based on the patient's, surgeon's, and anesthesiologist's comfort with the technique.

Positioning

The vast majority of lumbar spine surgery is performed with the patient in prone position with all the potential associated caveats: airway edema, endotracheal tube dislodgement, eye injury, neck manipulation, abdominal pressure, upper and lower extremities, and positioning difficulties. The geriatric population can be especially vulnerable due to associated conditions like osteoporosis or undiagnosed cervical spine pathology. Advanced arthritis (not limited to the spine) may complicate positioning of the arms and shoulders. Great attention should be paid during turning (e.g., maintaining in-line neck stabilization) and also after achieving prone position (neutral neck position, extra padding).

Monitoring

Intraoperative monitoring in patients undergoing lumbar spine surgery focuses on two areas that are closely interrelated: neurophysiologic monitoring of the spinal cord to ensure integrity of neural pathways and hemodynamic monitoring to ensure adequate perfusion pressure to vital organs.

Intraoperative monitoring of the spinal cord includes somatosensory evoked potentials (SSEP), motor evoked potentials (MEP), and electromyography (EMG) which can be used alone or in combination. Numerous factors can attenuate evoked potentials including hypotension, hypothermia, anemia, and anesthetics. SSEPs and MEPs are more sensitive to inhalational agents, so typically an intravenous technique is preferred although low concentration of inhalational drugs (< 0.5 MAC) is acceptable. Regardless of technique and drug selection, maintaining a steady anesthetic state in addition to communication with the surgeon and neurophysiologist is paramount in order to establish adequate baselines and parameters for monitoring. As with many anesthetic drugs or techniques, *how* one uses it may be more important than *what* one uses.

Aging can significantly alter drug pharmacology. Pharmacokinetic changes include a reduced volume of distribution (due to decreased total body water), potential sequestration of lipid soluble drugs (due to increased body fat), and prolonged elimination time. Overall, geriatric patients are likely to be more sensitive to anesthetic drugs due to age-related pharmacodynamics changes in addition to the potentially decreased clearance.

The goal for hemodynamic monitoring is (in theory) simple: maintaining adequate perfusion of the vital organs. This is important for all patients but especially for the elderly as their limited reserve makes them susceptible to complications such as neurologic and cognitive deficits, renal failure, or myocardial ischemia. While this goal appears straightforward, monitoring the perfusion pressure of end organs is difficult in clinical practice. Generally, perfusion pressure is calculated as the difference between mean pressure (MAP) and end-organ pressure but this may be overly simplified and not take into account regional differences in blood flow and organ physiology. Both the brain and the spinal cord can autoregulate blood flow within a wide range of MAPs (typically 50–150 mm Hg), but newer research shows that the lower limit of autoregulation may be higher than previously believed [103]. In addition, other local factors (such as spinal stenosis, retractor pressure) can cause regional ischemia even at "safe" MAPs. In clinical practice, it is common to maintain MAP close to (or above) the baseline levels while paying close attention to changes in neurophysiologic parameters. This translates into use of multiple/multimodal monitoring techniques, low threshold for placement of invasive monitors, higher likelihood of vasoactive infusions, and above all continuous vigilance as no single approach can be considered best for all patients.

Postoperative Visual Loss (POVL)

POVL is a rare yet devastating complication associated with spine surgery, and the American Society of Anesthesiologists established a registry in an attempt to delineate the causes [104]. Risk factors include prolonged prone positioning, obesity, significant blood loss, and anemia. Although advanced age has not been specifically linked to POVL, many elderly patients may have comorbidities such as vasculopathy and optic neuropathy that can contribute to POVL. Further, they can be exposed to prolonged surgeries that include significant blood loss due to age-related spine characteristics (poor bone quality).

Enhanced Recovery and Spine Surgery

There are wide variations reported in complication rates, length of stay (LOS), postoperative pain, and functional recovery after spine surgery which makes a strong argument for implementation of enhanced recovery pathways [105]. However, spine surgery lags significantly behind other orthopedic procedures like hip and knee replacement. Key among the reasons is that lumbar spine surgery encompasses different procedures with a wide range of indications. As mentioned before, standards of care for many lumbar diseases have not been established and different procedures have been shown to be beneficial for various pathologies.

As a result, spinal ERAS protocols are few, very recent, and applied to a small number of patients when compared to pioneering surgical specialties such as colorectal. Spinal ERAS is very much in its infancy; there are no spinal surgery protocols on the ERAS Society website. There is a paucity of research with the few relevant studies being nonrandomized and non-blinded. Fleege et al. [106] reported a reduction in hospital stay from 10.9 to 6.2 days in patients undergoing stabilization of one or two segments for degenerative lumbar spine pathologies. Blackburn et al. [107] described a spinal enhanced recovery program that included 21 clinical pathway interventions throughout the perioperative period. Intraoperative interventions included: use of minimally invasive techniques when possible, a standardized analgesic regimen aimed to reduce reliance on opioids, epidural and local infiltrations of local anesthetics, and blood loss prevention using tranexamic acid. After implementing this protocol, length of stay was reduced by 52% (from 6 to 2.9 days) and readmission rates decreased from 7% to 3%. Wang et al. [108] reported on 42 consecutive patients (mean age 66.1 ± 11.7 years) treated with a new minimally invasive trans-foraminal interbody fusion and showed a reduction in the hospital stay from 3.9 to 1.29 days compared to standard fusion technique previously used. While there were certain interventions that could be labeled as "ERAS components" such as the use of liposomal bupivacaine for analgesia in order to minimize opioid consumption, it appears that the change in surgical technique from open to endoscopic/minimally invasive was mostly responsible for the improvement in outcomes reported. This view was tempered however as the authors concluded that their long-term follow-up data were insufficiently powered to draw definitive conclusions as to efficacy and safety of the fusion procedure.

Multimodal Pain Management in Spine Surgery

ERAS by its definition is a multimodal and multidisciplinary approach where small incremental gains lead to overall improvements in patient outcomes. Multimodal pain management is an integral component of ERAS and is almost exclusively the domain of the anesthesiologists. This is extremely important as spine surgery with fusion ranks very high on the surgical pain scores [109] particularly in the first three postoperative days. There is an increasing body of research on multimodal analgesia although it is mostly geared toward the general population and not toward elderly patients specifically. While the review of geriatric pain management is beyond the scope of this chapter, it is important to remember a few important principles: (1) pain perception is an inherently subjective experience and can be substantially altered in an older patient, (2) individuals may exhibit particular sensitivity to opioid analgesics, and (3) opioid-sparing techniques including regional and neuraxial can be particularly helpful in geriatric patients.

Opioids remain a mainstay of perioperative analgesia after major spine surgery, but their well-publicized potential for side effects (short- and long-term) has catalyzed the search for safe and effective alternatives and adjuvants. A recent review by Devin and McGirt [110] supports the multimodal approach while suggesting that chronic opioid use in the preoperative period may have a negative impact on outcomes following spinal procedures. The authors used the North American Spine Society grades of recommendation for reviews: Good evidence (Grade A) for Level I studies with consistent findings, fair evidence (Grade B) for Level II or III studies with consistent findings, and insufficient or conflicting evidence (Grade I) defined as inconsistent findings or lack of investigation. The authors found good evidence (Grade A) that acetaminophen, gabapentinoids, neuraxial blockade, and extended-release local anesthetics reduce postoperative pain and opioid requirements. One important caveat regarding extended-release local anesthetics (such as liposomal bupivacaine) is that the vast majority of research has been conducted in other types of procedures and not in spinal surgery. There is fair evidence (Grade B) that nonsteroidal anti-inflammatory drugs (NSAIDs) decrease postoperative pain without reducing bone healing and fusion rates. Caution is still advised as the benefits of these drugs should be considered against the risks of hemorrhage, gastric ulceration, and renal toxicity especially in the geriatric population. Last but not least, Devin and McGirt concluded there was mixed/conflicting evidence that ketamine decreases postoperative pain or opioid usage after spine surgery, somewhat surprising and disappointing findings given the recent resurgence and newfound popularity of ketamine.

Dunn et al. [111] have also reviewed novel approaches to analgesia for major spine surgery and while they presented the evidence differently than Devin and McGirt, the findings were similar. Dunn et al. found high-level of evidence to support the use of opioids, acetaminophen, gabapentinoids, and N-methyl d-aspartate (NMDA) receptor antagonists for analgesia in spine surgery. There was promising, but limited evidence favoring the use of α-2 receptors agonists (dexmedetomidine) and intravenous lidocaine. The authors placed neuraxial opioids and NSAIDs in a third category; while they are useful analgesics, their use is limited due to concerns for infection and neurologic injury after surgery (neuraxial techniques) and bleeding and bone-healing risks (NSAIDs). It is important to highlight that other important nuances/differences were present within these broad categories. For example, in the NMDA receptor antagonist class (methadone, magnesium, ketamine), the data supporting methadone and magnesium was favorable but limited, especially for magnesium. Ketamine has been studied more extensively; however, the results are mixed and some studies showed no benefit, similar to data reported by Devin and McGirt; however, the authors still recommended it as a useful adjuvant in spine surgery. Also, a majority of the studies reviewed involved patients undergoing "minor" spine surgery (discectomy, single-level laminectomy) where pain patterns are likely to be different from patients undergoing more invasive surgeries.

Based on the available evidence supporting multimodal therapy, McDunn et al. have proposed a stepwise (ladder) approach for perioperative analgesia based on the type of surgery: minor (laminectomy, discectomy), moderate (1–2 level fusion), major (multilevel fusion). Patients undergoing minor surgery can be treated with opioids and acetaminophen. For patients having moderate surgery, ketamine and/or lidocaine can be added to the previous regimen. Finally, patients undergoing major procedures may benefit from preoperative gabapentinoids, intraoperative methadone, or neuraxial anesthesia in addition to previous modalities. While this approach can be seen as common sense, further research is needed as there is a lack of evidence regarding optimal perioperative protocols and pathways.

Summary

Aging populations and elderly patients' desire to remain active and maintain their independence are likely to increase the need for surgery, especially in orthopedics and spine.

Enhanced recovery protocols can be especially important for the geriatric population. Lumbar surgery lags significantly behind (but ahead of cervical spine surgery) other surgical specialties. A better understanding of the preoperative chronic pain state, pharmacokinetic and dynamic changes, and individual differences is key for geriatric patients. It is paramount to address the heterogeneity of the surgical procedures with respect to this patient population in designing pathways to improve the perioperative process and improve outcomes.

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