Chapter 4

Vertebral Augmentation (Kyphoplasty and Vertebroplasty) Complications and Management, From Recent Literature

Ozan Aydoğdu[1]

Melih Furkan Durak[2]

Abstract

Vertebral augmentation (VA), particularly percutaneous vertebroplasty and kyphoplasty, is widely used for painful osteoporotic vertebral compression fractures and selected neoplastic lesions. While these procedures provide rapid pain relief and functional improvement, they carry a distinct spectrum of complications that require structured prevention, early recognition, and timely management. This chapter summarizes recent literature on VA from 2020–2025 and integrates it into a pragmatic, complication-focused framework. Patient selection and timing are reviewed with an emphasis on imaging–pain concordance, fracture acuity, and competing surgical options. Peri-procedural workflow is detailed, including positioning, local anesthesia with light sedation, and the growing role of erector spinae plane blocks to reduce opioid requirements in frail patients. Technical sections address uni- versus bipedicular access, cement viscosity, vertebral venography and unsubtracted roadmap techniques, and radiation hygiene. Major complication domains are then discussed: needle- and trajectory-related vascular, pleural and neural injuries; cement-injection–related events such as intradiscal, anterior/lateral and posterior epidural leakage; venous run-off leading to pulmonary and cardiac cement embolism; infectious sequelae including discitis, osteomyelitis and epidural abscess; and index- and adjacent-level fractures driven by cement distribution and bone quality. For each domain, the chapter provides checklists and algorithms for intra- and post-procedural

1 Corresponding Author: MD Specialist Neurosurgeon, Muğla Training and Research Hospital Department of Neurosurgery, E-mail: md.o.aydogdu@gmail.com – ORCID: 0000-0002-5998-2673

2 MD Neurosurgery Resident, Muğla Sıtkı Koçman University Faculty of Medicine Deparment of Neurosurgery, E-mail: melihfdurak@gmail.com, ORCID: 0000-0002-2883-9698

https://doi.org/10.58830/ozgur.pub1087.c4321

triage, imaging, and definitive management, alongside a follow-up pathway that couples symptom surveillance with osteoporosis and fracture-risk stewardship. When performed with meticulous technique, evidence-based analgesia, and proactive complication management, VA remains a safe and effective option in appropriately selected patients.

1. PATIENT SELECTION AND INDICATIONS

Vertebral augmentation (VA) is considered for acute or subacute painful osteoporotic vertebral compression fractures (OVCFs) with imaging–pain concordance after a trial of optimized conservative therapy; selected neoplastic pathologies with mechanical pain also benefit. High-quality summaries emphasize individualized decision-making that balances analgesia and function against procedural risks [1]. Guideline frameworks and meta-analyses suggest comparable pain relief between posterior vertebroplasty (PVP) and posterior kyphoplasty (PKP), with differences in cost, height restoration, and cement leakage profiles [2]. Unipedicular approaches can reduce operative time and radiation exposure compared with bipedicular access without compromising outcomes in many OVCFs; however, bipedicular access remains valuable when midline crossing, height restoration, or cement distribution is suboptimal [5].

Clinical pearls & pitfalls — Indications

- Confirm fracture acuity and pain concordance (STIR hyperintense edema; focal percussion pain).
- Evaluate posterior wall compromise, canal stenosis, or retropulsion pre procedure.
- PKP should be considered when height restoration/kyphosis correction is prioritized; PVP should be considered for cost and speed.
- Severe cardiopulmonary disease favors local anesthesia and light sedation strategies.

2. PERI-PROCEDURAL WORKFLOW

2.1. Patient Positioning (Prone) and Anesthesia Strategies

Prone positioning with neutral abdominal pressure optimizes venous return and improves fluoroscopic visualization. Most VA procedures can be performed under local anesthesia and light intravenous sedation. Regional techniques (e.g., erector spinae plane block) are increasingly used to improve comfort in frail patients and may reduce opioid exposure [6–9,13]. General anesthesia is reserved for select cases (e.g., severe anxiety and prolonged

multilevel work), acknowledging airway and cardiopulmonary risks in the prone position [11].

Checklist — Pre-procedure safety

☐ Consent includes leakage/embolism, neural injury, infection, adjacent level fracture

☐ Review anticoagulation/antiplatelets; correct coagulopathy

☐ Screen for contrast allergy; have non-ionic/alternative plan

☐ Prone positioning with chest/pelvic bolsters; protect pressure points; padding for eyes

☐ Baseline neuro exam and pain map documented

☐ Antibiotic prophylaxis per institutional policy

2.2. Access and Technical Pearls (Unipedicular/Bipedicular; Cement Choice/Viscosity; Vertebrography)

Access: Unipedicular transpedicular access suffices for most thoracolumbar OVCFs; switch to bipedicular access when midline crossing is inadequate or distribution is uneven [5].

Cement and viscosity: High-viscosity PMMA reduces overall leakage rates compared to low-viscosity formulations, with similar disability outcomes and small pain advantages in some analyses [3,4].

Injection: Continuous biplanar fluoroscopy is used; injection is performed during the doughy phase at low pressure with frequent pauses.

Vertebrography/venography: Historical venography shows limited predictive value for leakage and may obscure cement visualization; selective use or unsubtracted roadmap alternatives are reasonable [30–32].

Clinical pearls & pitfalls — Access & cement handling

- Target the anterior third of the vertebral body on the lateral view and stay within the pedicle walls on the AP view.
- Stop rules: halting injection if cement approaches posterior third, epidural veins, foramina, or disc space.
- Vertebral body lavage should be considered, and volume should be limited to reduce pressure and leakage risk.
- Prefer high-viscosity cement and avoid injection during very low-viscosity phases.

3. COMPLICATIONS AND MANAGEMENT

3.1. Allergy or Hypersensitivity to Bone Cement (PMMA)

True allergy to PMMA or initiators (e.g., benzoyl peroxide, N, N-dimethyl-p-toluidine) is rare but has been reported, mostly in the arthroplasty literature. Pre-existing severe contact allergy or prior implant reactions warrant pre-procedure dermatology/immunology input and patch testing. If intra- or post-procedure anaphylaxis is suspected (rash, hypotension, bronchospasm), manage as peri-anesthetic anaphylaxis, avoid re-exposure, and consider alternative materials or non-cement stabilization strategies [16,17].

Algorithm 1 — Suspected cement hypersensitivity

1) Stop the infusion/injection, call for help, and secure the airway/IV access.

2) Treat as anaphylaxis according to protocol (IM epinephrine, antihistamine, corticosteroid, fluids).

3) Send tryptase within 1–2 h and document the products used (cement brand, additives, and antibiotics).

4) Post-event referral for patch/lymphocyte Transformation Test (LTT) and planning future avoidance.

3.2. Technical/Needle-Related Complications

3.2.1. Intraprocedural fracture mobilization/retropulsion

Sudden pain, a change in the fluoroscopic silhouette, or posterior wall movement suggests mobilization. Inflation/injection is stopped, biplanar views are reassessed, and augmentation is aborted if canal compromise is imminent. Decompression/fusion is reserved for symptomatic retropulsion cases.

3.2.2. Neural injury during guide/needle placement

Pedicle breach and foraminal violation risk radicular or cord injuries. The Jamshidi trajectory should be central to the AP view and below the pedicle roof on the lateral view. Neuromonitoring can be considered in patients with complex anatomy. Immediate new deficits warrant CT and neurosurgical procedures. Additionally, it is important to avoid deep sedation in order to monitor the development of deficits. Corticosteroid treatment should be initiated in the event of deficits.

3.2.3. Anterior cortical breach with injury

Anterior cortical violation at thoracic or lumbar levels can injure segmental/intercostal arteries, the aorta (especially left-sided thoracic–upper lumbar), iliac veins/IVC (mid-lower lumbar), or produce retroperitoneal/psoas hematoma through muscular or venous injury. The risk is amplified by over-advancement of the cannula beyond the anterior cortex, oblique/lateral trajectories, severe osteoporotic collapse that distorts landmarks, and low-resistance cancellous "run-through" when switching instruments. Balloon augmentation near a deficient anterior wall can also propagate micro-tears into adjacent vascular planes [21–24].

Checklist — Needle & trajectory safety

- Plan pedicle entry on CT; recognize small/rotated pedicles
- Advance under true biplanar fluoroscopy; avoid oblique illusions.
- Confirm tip within medial pedicle wall before crossing posterior cortex.
- Abort if uncontrolled pain, paresthesia, or unexpected resistance

Immediate red flags:

- Sudden hypotension, tachycardia, pallor, diaphoresis.
- New pleuritic chest pain or dyspnea (hemothorax), or abdominal/flank/groin pain with retroperitoneal fullness (psoas/retroperitoneal bleed).
- Rapid hemoglobin drop or escalating analgesic requirement.
- Any of the above → Treat as active hemorrhage until proven otherwise [21–24].

First actions (on table):

- Stop instrumentation/injection; maintain cannula position to avoid worsening the laceration.
- Activate hemorrhage protocol: two large-bore IVs, cross-match, balanced transfusion (PRBC/FFP/platelets), permissive hypotension if appropriate.
- Reverse anticoagulation where indicated (vitamin K, PCC/FFP, platelet transfusion).
- Point-of-care ultrasound: quick screen for hemothorax/large effusion; look for retroperitoneal free fluid if feasible.
- Prepare for expedited CT angiography (CTA) and alert vascular surgery/interventional radiology (IR) early [21–24].

Imaging/triage:

- CTA chest/abdomen/pelvis (arterial ± venous phases) is the diagnostic workhorse: defines the bleeding source (segmental/intercostal vs aortic or iliac venous injury), trajectory, hematoma extent, and active extravasation.
- Unstable patient with strong clinical suspicion → direct to IR or OR for damage-control endovascular or surgical hemostasis, with imaging deferred or limited to targeted views as logistics allow [21–24].

Definitive management options:

- Segmental/intercostal arterial injury:
  - Selective catheterization with coil or plug embolization is first-line.
  - When the defect is larger or near the origin, covered stent can preserve flow while excluding the injury.
  - During thoracolumbar work, be mindful of spinal cord perfusion (artery of Adamkiewicz)—use super-selective embolization and document levels treated; perform frequent neuro-checks post-procedure [21–24].
- Aortic injury (rare): If contained tear or focal laceration is identified, thoracic endovascular aortic repair (TEVAR) provides rapid control; massive, uncontained hemorrhage may require hybrid or open repair depending on resources [21–24].
- Iliac vein/IVC injury: Balloon tamponade (occlusion balloon) to stabilize, followed by covered-stent reconstruction when anatomy permits; otherwise open venous repair if endovascular options fail. Correct coagulopathy and maintain normothermia/ionized calcium for clot function [21–24].
- Psoas/retroperitoneal hematoma:
  - Many are venous/low-pressure and respond to resuscitation, reversal of anticoagulation, analgesia, and monitored observation.
  - Ongoing expansion, femoral neuropathy, or active arterial blush on CTA → targeted IR embolization; compartment syndrome is rare but mandates surgical evaluation [21–24].
- Hemothorax from intercostal injury: Insert large-bore chest drain; persistent hemorrhage → intercostal/segmental artery embolization or VATS for control and evacuation [21–24].

Post-event care & surveillance:

- ICU/step-down monitoring with hemodynamics and Hb/hematocrit checks (e.g., q6–8 hours initially).
- Consider repeat CTA (24–48 h) for high-risk arterial repairs or large hematomas to confirm stability.
- Start/restore VTE prophylaxis when hemostasis is secure; if a covered stent was used, follow local antiplatelet protocols.
- After intercostal/segmental embolization, perform scheduled neurological assessments for early signs of spinal cord ischemia (motor/sensory changes).
- Document cement brand/lot, volumes, exact levels, and embolized segments, with a brief morbidity review for learning points [21–24].

At thoracic levels, lateral or anterior cortical breaches may injure pleura/lung or intercostal–segmental vessels, leading to pneumothorax, hemothorax, or hemopneumothorax; rapid, multidisciplinary management is required [41–44]. Cement may also track along venous/arterial pathways and precipitate hemorrhagic or embolic sequelae in select cases [43,44]. Over-advancement beyond the anterior cortex or lateral wall violations in upper thoracic vertebrae increase pleural/pulmonary injury risk; high-pressure injection or venous egress can worsen extraosseous spread [41,43,44].

Clinical presentation: Sudden pleuritic chest pain, dyspnea, desaturation, tachycardia, and reduced breath sounds should trigger immediate evaluation; hemodynamic instability mandates prompt resuscitation [41,42].

Diagnostic approach: Point-of-care ultrasound (absent lung sliding/"barcode" sign) offers rapid bedside confirmation of pneumothorax; portable/upright chest radiography supports confirmation and quantification. Suspected vascular injury or active bleeding warrants CT angiography to assess intercostal/segmental arteries [41,42,44].

Management:

- Pneumothorax: Stable/small → observation with O_2; symptomatic or larger → needle aspiration or intercostal chest tube; persistent air leak → thoracic surgery (VATS/pleurodesis) per BTS 2023 [41,45].
- Hemothorax/hemopneumothorax: Chest drain (institutional standard; ≥24F acceptable), resuscitation; retained hemothorax or ongoing bleeding → early VATS (24–72 h) and/or endovascular

embolization (intercostal/segmental artery) in line with EAST recommendations and case experience [42–44].

- Massive hemothorax/hemodynamic instability: Emergency thoracic/vascular surgery and/or IR intervention [42,44].

Prevention (technical pearls)

- Pre-op CT planning of anterior cortex depth and pedicle trajectory at each level; beware rotational deformity.
- Use true AP and lateral views (avoid obliquity); advance incrementally, feeling for cortical resistance—do not "punch through."
- Consider depth-limit devices/stop rings on drills/reamers.
- If the patient (under local/sedation) reports sudden deep/visceral pain, pause and re-image.

3.3. Cement-Injection–Related Complications

3.3.1. Intradiscal leakage

Mechanism & risk factors: Endplate fissuring, intravertebral cleft, severe vertebral collapse, low-viscosity cement, higher injection pressures, larger fill volumes and delayed timing are associated with intradiscal tracking [25–28].

Clinical significance. Intradiscal cement elevates stress at adjacent endplates and has been linked to a higher incidence of adjacent vertebral fractures (AVF) in observational series and biomechanical models [25–28].

Intra-procedural recognition. Linear opacification crossing the endplate toward the disc or a fan-shaped spread along the disc plane on lateral fluoroscopy.

Management (during the case): Stop injection immediately when cement approaches the endplate/disc. Allow cement to thicken (higher viscosity), re-orient the cannula to a more central trabecular path, and resume with small, intermittent aliquots only if safe. If leakage has occurred, avoid further contact with the involved endplate; target a more central distribution.

Post-procedure strategy: Educate patients about AVF symptoms (new focal pain above/below the treated level); use targeted radiographs/CT if symptoms develop. Consider short-term external bracing in high-risk morphologies. Prioritize bone-health optimization (calcium/vitamin D sufficiency, anti-resorptive or anabolic therapy per risk) to mitigate AVF risk [25–28].

Prevention: Maintain ≥3–5 mm clearance from endplates. Prefer higher-viscosity cement; lowpressure, staged injections with continuous lateral view. Terminate immediately at the first sign of discal tracking [25–28].

3.3.2. Anterior/lateral leakage

Typically, asymptomatic. Reduce injection pressure, pause, and allow polymerization; reposition the cannula if necessary. Persistent extravertebral pooling near vessels warrants cessation and post-procedure observation.

Mechanism & typical course: Extra-periosteal anterior/lateral pooling is often clinically silent and limited once polymerization occurs. Clinical relevance increases near pleura/lung (thoracic) or retroperitoneal vessels/viscera (lumbar).

Early detection. On lateral fluoroscopy, look for crescent/"pooling" of cement outside cortex. Patients may report localized heat or burning, suggesting superficial thermal irritation.

Management: Pause injection, allow viscosity to rise, and re-direct the cannula along a safer central trabecular path. Superficial/soft-tissue pooling; conservative care (cooling packs, analgesics) typically suffices. If spread approaches major vessels/pleura, stop the procedure; perform post-procedure targeted imaging and observe clinically. Escalate to vascular/IR or thoracic consultation if symptoms evolve.

Stop thresholds: Worsening extraosseous pooling, encroachment on pleura/vascular structures, or inability to achieve safe intravertebral distribution → terminate the injection. Avoid the temptation to "seal the leak" by adding more cement under pressure.

Prevention: Keep the needle tip central and anterior within the vertebral body; avoid hugging the cortex. Use low-pressure, intermittent injections with continuous lateral monitoring; reposition at the first hint of extra-periosteal spread.

3.3.3. Posterior (spinal canal) leakage

Why it matters. Posterior/epidural leakage can compress neural elements; risk rises with posterior wall defects, low-viscosity boluses, high-pressure injection, and injections performed near the posterior third of the body [29].

Emergency triage**:**

-Immediate stop of injection for any new motor deficit, rapidly progressive radicular pain, saddle anesthesia, or sphincter disturbance.

-Consider high-dose corticosteroids (as a short bridge if not contraindicated), then obtain urgent MRI/CT to define the extent/location of cement [29].

If imaging confirms compressive cement with concordant neurological deficit → early decompression with foreign-body removal under microscopy (ultrasonic tool or high-speed burr may assist), plus hemostasis and neural decompression [29]. Small, non-compressive, asymptomatic epidural deposits → close observation with a low threshold for re-imaging if symptoms evolve; routine steroids are not mandatory in stable, asymptomatic cases.

Peri-operative details to document: Level(s), needle trajectory, cement brand/lot, total volume, and an estimate of epidural burden/consistency; this supports shared decision-making and quality review.

Prevention**:** Keep the working tip anterior to the pedicle midpoint on lateral view and avoid posterior third injection. Inject during the doughy (higher-viscosity) phase with small aliquots under continuous lateral fluoroscopy**.** Abort if epidural venous opacification or posterior tracking is seen [29].

Discharge & follow-up: Record a thorough neurological exam at discharge; schedule early clinical review. Re-image promptly for recurrent/worsening pain or new deficits.

3.3.4. Venous leakage → pulmonary cement embolism (PCE; venous pathways)

Cement can enter basivertebral and epidural veins, then the azygos/hemiazygos/segmental systems to the right heart and pulmonary arteries. Asymptomatic PCE is not uncommon on screening radiography/CT; most cases are observed, while symptomatic or large burden may merit anticoagulation and, rarely, percutaneous or surgical retrieval [10,25,33–36].

Algorithm 2 — Suspected pulmonary cement embolism (PCE)

- Immediate: O2, ECG/SpO2, vitals; obtain chest X-ray.
- If symptomatic or hypoxic, get CT pulmonary angiography.
- Risk-stratify: small/asymptomatic → observation;
  - § symptomatic/segmental-central burden → consider anticoagulation if no bleeding risk,
  - § massive/intracardiac burden or valve entrapment → urgent interventional radiology/cardiothoracic consult for retrieval.
- Report and counsel: discuss recurrence prevention (higher viscosity, slower injection, limit volume, vertebral lavage).

4. POST-OPERATIVE COMPLICATIONS

4.1. Injury to Soft Tissues Involved in Access (Paraspinal Muscles)

Local myofascial pain is frequent but self-limited; manage with ice/heat, short NSAID course (if safe), and early mobilization. Ultrasound-guided trigger-point injections or ESP blocks are options for refractory cases.

4.2. Infection (Discitis, Osteomyelitis, Paravertebral/Epidural Abscess; Systemic Infection)

Post-VA infection is rare (<1% in large series) but potentially devastating. Risk factors include diabetes, immunosuppression, prior spondylitis, and breaches into disc space. Work-up includes CBC, CRP/ESR, MRI with contrast, and—when feasible—CT-guided aspiration for culture. Begin pathogen-directed IV antibiotics; failure of medical therapy or neurologic compromise warrants debridement and, if needed, reconstruction [12,37–39].

Algorithm 3 — Work-up and management of suspected post-VA infection

1) Labs: CBC, CRP/ESR; blood cultures if febrile.

2) MRI with contrast (look for discitis/osteomyelitis, epidural/paravertebral abscess).

3) Image-guided aspiration/biopsy prior to antibiotics when stable; if unstable, start broad IV therapy then tailor.

4) Surgical consult: indications include neurologic deficit, instability/deformity, abscess not amenable to percutaneous drainage, or failure of IV therapy.

5) Duration: typically 6–12 weeks total IV/PO based on organism and response.

4.3. Index-Level Pedicle/Vertebral Issues and Adjacent-Level Fractures

Pedicle fractures or instrument-related pain after VA are uncommon; treat symptomatically and evaluate for occult fracture. Adjacent-level fractures remain a clinical concern. Contemporary evidence suggests risk is driven by osteoporosis severity, cement distribution, and intradiscal leakage; optimize anti-osteoporotic therapy and avoid endplate/disc contact during injection [5,25–28].

5.FOLLOW-UP PATHWAY (CLINICAL, IMAGING, AND BONE-HEALTH STEWARDSHIP)

Early (2–6 weeks): pain/function check, wound review, and red-flag screening (fever, new neuro deficit, dyspnea). Imaging if new/worsening pain or neurologic symptoms.

Bone-health: ensure calcium/vitamin D sufficiency; start anti-resorptive or anabolic therapy per fracture risk (e.g., NOGG framework); fall-prevention and sarcopenia screening [40].

Longitudinal (3–12 months): DXA if no recent assessment; monitor adherence and evaluate for new fractures.

Checklist — Follow-up essentials

☐ Pain/function (VAS/ODI) and analgesic use
☐ New symptoms: radicular pain, dyspnea, fever, wound issues
☐ Plan for DXA/FRAX; start/optimize osteoporosis therapy
☐ Physiotherapy and falls clinic referral when indicated
☐ Educate about signs of PCE and infection

6. PRACTICAL RECOMMENDATIONS TO MAXIMIZE COMFORT, REDUCE RADIATION, AND SHORTEN PROCEDURE TIME

- Use unipedicular access when feasible; pre-plan entry on CT.
- Adopt consistent stop-rules and announce them to the team.
- High-viscosity cement; slow, intermittent injection under live biplanar fluoroscopy.
- Radiation hygiene: tight collimation, pulse fluoroscopy, low-dose settings, last-image hold; lead glasses/thyroid shields for staff; avoid hands in beam.
- Analgesia protocol (local infiltration ± ESP block) to minimize sedation.
- Prepare algorithm cards and checklists in the procedure room.
    -

MASTER CHECKLIST — VERTEBRAL AUGMENTATION SAFETY & EFFICIENCY

Pre-procedure

☐Confirm fracture acuity and pain–imaging concordance (STIR edema; focal percussion).

☐ Exclude active infection; review temperature, labs, and any prior spondylitis/discitis.

☐ Neurologic exam: rule out cord/cauda symptoms needing decompression rather than augmentation.

☐ Coagulation plan: anticoagulants/antiplatelets reviewed; correct coagulopathy per institutional policy.

☐ Medical optimization: glycemic control, cardiopulmonary assessment (prone tolerance, OSA/COPD).

☐ Imaging plan: pre-op CT/MRI to assess posterior wall, endplates, clefts, venous channels.

☐ Access plan: uni- vs bi-pedicular; target midline crossing; bailout strategy if distribution is poor.

☐ Cement plan: high-viscosity PMMA; expected volume range; stop-rules declared to team.

☐ Radiation plan: pulse rate, collimation, C-arm geometry, personal shielding, last-image hold usage.

☐ Prophylaxis: antibiotics per policy; DVT prophylaxis if indicated; informed consent completed.

Intra-procedural — Trajectory, Injection & Radiation

☐ Positioning: abdomen free; chest/pelvic bolsters; eyes/pressure points protected; lines secured.

☐ Time-out: correct level confirmed on AP/true lateral; instrument and cement brand recorded.

☐ Trajectory: stay within pedicle walls (AP); below pedicle roof (lateral); confirm before cortical crossing.

☐ Test run: optional vertebrography or careful trial injection; abort if early epidural/venous opacification.

☐ Injection: doughy phase; small aliquots; continuous lateral view; frequent pauses.

☐ Stop-rules: halt if cement approaches posterior third, foramina, or disc space.

☐ Leak management: pause to allow polymerization; reposition cannula; do not 'push through'.

☐ Radiation hygiene: plan shots; minimize magnification; keep detector close/tube far; document DAP/fluoro time.

Focused Algorithm — Suspected Pulmonary Cement Embolism

☐ If venous run-off seen: stop, reassess needle, consider waiting for viscosity increase or redirecting.

☐ If respiratory symptoms: O2, vitals, ECG; CXR; escalate to CTPA if indicated.

☐ Small/asymptomatic PCE: observation; consider anticoagulation based on burden/risk.

☐ Symptomatic/central PCE: anticoagulation unless contraindicated; consult IR/cardiology for retrieval options.

☐ Massive/intracardiac: urgent cardiothoracic/IR intervention; advanced support as needed.

Post-procedure & Discharge

☐ Immediate neuro check; document new pain/deficits; targeted imaging only if symptoms.

☐ Puncture-site check; analgesia/antiemetics; early mobilization.

☐ Discharge red flags explained: fever, wound issues, new radicular pain/weakness, dyspnea/pleuritic pain.

☐ Infection pathway if suspected: labs (CBC, CRP/ESR), MRI with contrast; blood cultures; ID consult.

☐ Retropulsion/canal leak suspected: urgent MRI/CT; spine surgery consult for decompression if symptomatic.

☐ Bone-health plan: Ca/Vit-D, anti-resorptive vs anabolic per risk; DXA/FRAX scheduled; falls clinic referral.

☐ Follow-up timing: 2–6 weeks (clinical), 3–6 months (bone health/new fracture screen).

☐ Documentation: level(s), approach, cement brand/lot & volume, viscosity/phase, complications, DAP/fluoro time.

References

1. Hoffmann JJ, Preston G, Whaley J, Khalil JG. Vertebral augmentation in spine surgery. *J Am Acad Orthop Surg*. 2023;31(10):477-489. doi:10.5435/JAAOS-D-22-00958. PMID:36952673.
2. Rose LD, Bateman G, Ahmed A. Clinical significance of cement leakage in kyphoplasty and vertebroplasty: a systematic review. *Eur Spine J*. 2024;33:1484-1489. doi:10.1007/s00586-023-08026-3. PMID:37999769.
3. Wang Q, Sun C, Zhang L, et al. High- versus low-viscosity cement vertebroplasty and kyphoplasty for osteoporotic vertebral compression fractures: a meta-analysis. *Eur Spine J*. 2022;31(5):1122-1130. doi:10.1007/s00586-022-07150-w. PMID:35249143.
4. Chen WC, Tsai SHL, Goyal A, et al. Comparison between vertebroplasty with high- or low-viscosity cement and kyphoplasty: a network meta-analysis of cement leakage. *Eur Spine J*. 2020;30(9):2680-2690. doi:10.1007/s00586-020-06636-9. PMID:33145678.
5. Cao DH, Gu WB, Zhao HY, Hu JL, Yuan HF. Advantages of unilateral percutaneous kyphoplasty for osteoporotic vertebral compression fractures: a systematic review and meta-analysis. *Arch Osteoporos*. 2024;19(1):38. doi:10.1007/s11657-024-01400-8. PMID:38355802.
6. Patel IJ, Davidson JC, Nikolic B, et al. Consensus guidelines for the use of sedation and analgesia in adult patients undergoing interventional radiology procedures. *Cardiovasc Intervent Radiol*. 2020;43(3):327-343. doi:10.1007/s00270-020-02536-z. PMID:32556610.
7. The Royal College of Radiologists. *Safe Sedation, Analgesia and Anaesthesia Within the Radiology Department*. 3rd ed. London: RCR; 2024. Erişim: 13 Aralık 2025.
8. Oostvogels L, Weibel S, Meißner M, Kranke P, Meyer-Frießem CH, Pogatzki-Zahn E, Schnabel A. Erector spinae plane block for postoperative pain. *Cochrane Database Syst Rev*. 2024;2:CD013763. doi:10.1002/14651858.CD013763.pub3.
9. Orhon-Ergün M, Yıldırım F, Aydın T, et al. Comparison of the effectiveness of anesthesia methods on percutaneous kyphoplasty: erector spinae plane block versus local anesthesia. *Istanbul Med J*. 2022;23(2):149-153. doi:10.4274/imj.galenos.2022.13911.
10. Sun HB, Jing XS, Shan JL, Bao L, Wang DC, Tang H. Risk factors for pulmonary cement embolism associated with percutaneous vertebral augmentation: a systematic review and meta-analysis. Int J Surg. 2022;101:106632. doi:10.1016/j.ijsu.2022.106632

11. Papadopoulos EC, Edobor-Osula F, Gardner MJ, Lane JM, Helfet DL. Percutaneous balloon kyphoplasty with the patient under intravenous sedation. *AJNR Am J Neuroradiol*. 2011;32(4):649-652. PMID:21349952.
12. Yuan H, Li Y, Wang J, et al. Spinal infection after vertebral augmentation: a covert complication with serious havoc. *Arch Orthop Trauma Surg*. 2024;144(3):1461-1471. doi:10.1007/s00402-024-05205-9.
13. Ma J, Bi Y, Zhang Y, et al. Erector spinae plane block for postoperative analgesia in spine surgery: a systematic review and meta-analysis. *Eur Spine J*. 2021;30(12):3390-3403. doi:10.1007/s00586-021-06853-w.
14. Mullan C, Basu S, Wallace A, et al. Pulmonary cement embolisation after percutaneous vertebroplasty. *BMJ Case Rep*. 2023;16(2):e254292. doi:10.1136/bcr-2022-254292.
15. Morrison A, Chan RP, Sofocleous CT, Weintraub JL. Endovascular management of vertebroplasty cement embolism. *J Vasc Surg Venous Lymphat Disord*. 2024;12(3):101798. doi:10.1016/j.jvsv.2024.101798.
16. Pahlavan S, Hegde V, Bracey DN, Jennings JM, Dennis DA. Bone cement hypersensitivity in patients with a painful TKA: case series of revision using custom cementless implants. *Arthroplast Today*. 2021;11:20-24. doi:10.1016/j.artd.2021.08.006. PMID:34458366.
17. Bircher A, Friederich NF, Seelig W, Scherer K. Allergic complications from orthopaedic joint implants: the role of delayed hypersensitivity to benzoyl peroxide in bone cement. *Contact Dermatitis*. 2012;66(1):20-26. doi:10.1111/j.1600-0536.2011.01996.x.
18. Vasconcelos C, Gailloud P, Beauchamp NJ, Heck DV, Murphy KJ. Is percutaneous vertebroplasty without pre-treatment venography safe? Evaluation of 205 consecutive procedures. *AJNR Am J Neuroradiol*. 2002;23(6):913-917. PMID:12063238.
19. Xie SM, Cui LQ, Wang CL, et al. Contact between leaked cement and adjacent vertebral endplate induces a greater risk of adjacent vertebral fracture with vertebral bone cement augmentation biomechanically. *Spine J*. 2025; 25(2): 324-336. doi:10.1016/j.spinee.2024.09.021.
20. Gregson CL, Armstrong DJ, Bowden J, Cooper C, Edwards J, Gittoes NJL, Harvey N, Kanis J, Leyland S, Low R, McCloskey E, Moss K, Parker J, Paskins Z, Poole K, Reid DM, Stone M, Thomson J, Vine N, Compston J. UK clinical guideline for the prevention and treatment of osteoporosis. Arch Osteoporos. 2022 Apr 5;17(1):58. doi: 10.1007/s11657-022-01061-5
21. Alomari S, Planchard R, Lo SFL, Witham T, Bydon A. Aortic injury in spine surgery: what a spine surgeon needs to know. *Neurosurg Rev*. 2021;44(6):3189-3196. doi:10.1007/s10143-021-01527-z.
22. Han X, Sheng Y, Wu J, Wang W. Unretrievable IVC filter due to cement intravasation. *Cardiovasc Intervent Radiol*. 2022;45(7):1048-1050. doi:10.1007/s00270-022-03122-1.

23. Petousi N, Triantafyllou G, Skoularigis J, et al. Asymptomatic cement leakage into inferior vena cava after percutaneous vertebroplasty. *QJM*. 2022;115(1):49-50. doi:10.1093/qjmed/hcab201. PMID:34383987.
24. Mao Z, Xiong ZH, Li JF. Thoracic spinal cord injury and paraplegia caused by intradural cement leakage after percutaneous kyphoplasty: a case report. *World J Clin Cases*. 2024;12(10):1837-1843. doi:10.12998/wjcc.v12.i10.1837.
25. Lin EP, Ekholm S, Hiwatashi A, Westesson PL. Vertebroplasty: cement leakage into the disc increases the risk of new fracture of adjacent vertebral bodies. *AJNR Am J Neuroradiol*. 2004;25(2):175-180. PMID:14970018.
26. Chen J, Lu S, Chen Y, Zhang X, et al. Space between bone cement and bony endplate can trigger higher incidence of augmented vertebral collapse: an in-silico study. J Clin Neurosci. 2024;125:152-158. doi:10.1016/j.jocn.2024.05.020
27. Rho YJ, Choi WS, Kwon YJ, et al. Intradiscal cement leakage increases stress on adjacent endplates: a finite element analysis. *Sci Rep*. 2023;13:17303. doi:10.1038/s41598-023-43375-5.
28. Zhang W, Huang Y, Li X, et al. Effect of bone cement distribution on adjacent disc degeneration after vertebral augmentation in osteoporotic vertebral compression fractures. *Front Surg*. 2023;10:1256401. doi:10.3389/fsurg.2023.1256401.
29. Lin Z, Morishita S, Yamazaki M, et al. Surgical findings and precautions for removing cement that leaked into the spinal canal after balloon kyphoplasty: illustrative cases. *J Neurosurg Case Lessons*. 2024;9(8):CASE24796. doi:10.3171/CASE24796.
30. Pasciak AS, Gilula LA, Brown DB. Intraosseous venography in percutaneous vertebroplasty: does it predict cement leakage? *J Vasc Interv Radiol*. 2007;18(5):759-764.
31. Gaughen JR Jr, Jensen ME, Schweickert PA, Kaufmann TJ, Marx WF, Kallmes DF. Relevance of antecedent venography in percutaneous vertebroplasty for the treatment of osteoporotic compression fractures. *AJNR Am J Neuroradiol*. 2002;23(4):594-600. PMID:11950650.
32. Chen JY, Tsuang FY, Lin YH, Lee CW. Unsubtracted Roadmap Technique for Preventing Cement Leakage During Percutaneous Vertebroplasty: A Retrospective Cohort Study. World Neurosurg. (2023) 173:e140-e147. doi: 10.1016/j.wneu.2023.02.021
33. Chen JY, et al. Detecting asymptomatic cement pulmonary embolisms following vertebral augmentation using dual-energy computed tomography pulmonary angiography. J Formosan Med Assoc. 2025; doi:10.1016/j.jfma.2025.01.015

34. Zhan Y, Jiang J, Liao H, et al. Pulmonary cement embolism after percutaneous vertebroplasty or kyphoplasty: a systematic review. *Egypt J Bronchol*. 2023;17:51. doi:10.1186/s43168-023-00202-9.

35. Xu J, Liu Y, Sun Z, et al. Cardiac cement embolism after percutaneous vertebroplasty: case report and literature review. *Front Surg*. 2024;11:1464049. doi:10.3389/fsurg.2024.1464049.

36. Krueger A, Bliemel C, Zettl R, Ruchholtz S. Pulmonary cement embolism after vertebroplasty: incidence, risk factors and clinical outcome. *J Orthop Surg Res*. 2021;16:441. doi:10.1186/s13018-021-02472-9.

37. Park JW, Park SM, Lee HJ, et al. Infection following percutaneous vertebral augmentation with polymethylmethacrylate. *Arch Osteoporos*. 2018;13:47. doi:10.1007/s11657-018-0466-3. PMID:29637452.

38. Liao JC, Lai PL, Chen LH, Niu CC. Surgical outcomes of infectious spondylitis after vertebroplasty. *BMC Infect Dis*. 2018;18:555. doi:10.1186/s12879-018-3473-5. PMID:30424730.

39. Zampetakis K, Stavrakakis IM, Samartzidis K, et al. Infection Following Vertebroplasty or Kyphoplasty: A Systematic Review of Risk Factors, Treatment Options and Outcomes. *Global Spine Journal*. 2025;0(0). doi:10.1177/21925682251384614

40. Gregson CL, Armstrong DJ, Avgerinou C, et al. The 2024 UK clinical guideline for the prevention and treatment of osteoporosis: position paper of the National Osteoporosis Guideline Group (NOGG). *Arch Osteoporos*. 2025;20:119. doi:10.1007/s11657-025-01588-3.

41. BTS Pleural Guideline Development Group. British Thoracic Society Guideline for pleural disease. Thorax. 2023;78(Suppl 3):s1-s42. doi:10.1136/thorax-2022-219784. PMID:37433578.

42. Mowery NT, Gunter OL, Collier BR, Diaz JJ Jr, Haut E, Hildreth A, Holevar M, Mayberry J, Streib E. Practice management guidelines for management of hemothorax and occult pneumothorax. J Trauma. 2011;70(2):510-518. doi:10.1097/TA.0b013e31820b5c31.

43. Patel MB, Menaker J, Seamon MJ, et al. Management of simple and retained hemothorax: a practice management guideline from the Eastern Association for the Surgery of Trauma. Am J Surg. 2021;221(5):873-884. doi:10.1016/j.amjsurg.2020.11.032.

44. Rodríguez M, González de la Huebra Labrador T, Aranda JL. Diagnosis and treatment of hemothorax caused by intercostal artery pseudoaneurysm. Arch Bronconeumol. 2016;52(4):219. doi:10.1016/j.arbr.2016.02.008. PMID:26518657.

45. British Thoracic Society Pleural procedures Clinical Statement Group. British Thoracic Society Clinical Statement on pleural procedures. Thorax. 2023;78(Suppl 3).