RQ [##]: Should vascular shunting be performed prior to definitive bone fixation to minimise warm ischaemia time, or should it follow bony fixation?

Section 1: Background

High-energy extremity trauma presenting with concurrent long bone fractures and major arterial disruptions represents a limb-threatening emergency which requires swift and effective multidisciplinary management. The first question often faced by management teams is whether the limb can be salvaged – and while this depends on a multitude of factors, prolonged warm ischaemia time has been cited as the primary determinant of microvascular breakdown, compartment syndrome, rhabdomyolysis, and definitive limb loss. Hypoxic thresholds exceeding six to eight hours are universally associated with amputation rates as high as 86%. Being able to successfully salvage a limb in the setting of an open fracture with vascular injury is therefore directly contingent upon rapid restoration of blood flow.

A central dilemma that exists in the management of such injuries is the surgical sequence of two important steps: vascular repair restoring blood flow and skeletal stabilization – that is, whether primary orthopaedic bone fixation should precede vascular reconstruction to establish a stable skeletal framework in which vascular surgery may be more effectively executed, or whether immediate revascularization takes precedence. Proponents of early bone fixation argue that mechanical stability protects subsequent vascular repairs from iatrogenic disruption during fracture reduction that often involves correction of severe angulations, displacements and shortening. However, this strategy introduces operational delays, compounding warm ischemia. Conversely, a primary "vessel-first" strategy minimizes ischemia time but makes the vascular work technically challenging as the skeletal framework remains unstable.

Temporary intravascular shunting has emerged as an alternative 'damage-control' bridge. Shunting immediately restores distal arterial flow and cuts down the ischaemia time. At the same time, studies have indicated preference of provisional external fixation over definitive internal fixation to enable swift skeletal stabilization – following which, clean, tension-free definitive vascular reconstruction/repair can be executed without running the risk of immediate iatrogenic damage to the repair as the skeletal alignment has already been achieved in the previous step.
Studies that have incorporated temporary shunting in their management strategy are few – historical cohorts that have explored this surgical sequence question have only included direct vascular repair/reconstruction, leading to distinct outcome patterns which make resolution of this question difficult.

Section 2: Data extraction table

S No.	Author, Year, Country	Study Design	Sample Size	Study population (inclusion and exclusion criteria)	Groups compared	Results
1	Castro et al., 2025, United States (1)	Retrospective review	35 patients (29 -primary vascular, 6 - primary orthopaedic)	Patients ≥18 years with lower extremity long bone fractures/knee dislocations and associated vascular injury requiring repair. Exclusion: prisoner, pregnant, <90-day follow-up	Primary vascular intervention (VP) vs Primary orthopaedic intervention (OP)	Mean warm ischemia time was similar (360 min VP vs 320 min OP, p=0.52). Amputation rates did not differ significantly (3/29 VP vs 0/6 OP). No significant difference in intraoperative blood transfusion requirements or infection rates
2	Pfeifer et al., 2024, Switzerland (2)	Delphi consensus & systematic review	73 publications analyzed; 17 international experts	Literature regarding timing of major fracture care in polytrauma patients with multi-system injuries. Multiple questions explored.	Early vs Late definitive fixation; Sequencing of revascularization vs osteosynthesis	20 consensus statements generated – this included the following: For extremity arterial injuries approaching 6 hours of critical ischaemia, restoring flow takes absolute priority. Recommends intra-arterial shunting followed by temporary fracture stabilization.
3	Jin et al., 2022, China (3)	Retrospective cohort study	88 patients (98 legs)	Trauma patients with lower leg arterial injury and an unstable	Primary end-to-end anastomosis vs Autologous vein graft	Overall limb salvage rate was 91.8% (90/98 legs).

				bone fracture or knee dislocation treated with external fixation	under external fixator stabilization	Deep infection/osteomyelitis occurred in 3.4% (3 legs). Bone non-union/defect occurred in 17 legs, successfully treated via secondary internal staging or Ilizarov technique
4	Lewis et al., 2022, United States (4)	Retrospective cohort study	104 patients (19 Fracture fixation pre-revascularization (PRE), 85 fracture fixation post-revascularization (POST)	Adult patients requiring operative repair of concurrent long bone fracture and major arterial injury in the same extremity over 11 years	Fracture fixation pre-revascularization (PRE) vs fracture fixation post-revascularization (POST)	PRE group had significantly longer revascularization times (9.5 vs 5.8 hours; p=0.0002). PRE fixation independently predicted graft failure (OR 3.98; p=0.03) and amputation (OR 3.92; p=0.017)
5	Tunali et al., 2016, Turkey (5)	Retrospective review	22 patients	Adult patients with Gustilo-Anderson grade 3C open tibia fractures requiring vascular repair. Excluded: primary amputations.	Clinical evaluation of outcomes based on ischaemia time and MESS score	Secondary amputation rate was 36% (all due to vascular failure). Shunts placed initially for popliteal/trifurcation injuries with severe ischaemia, followed by temporary external fixation, then definitive repair
6	Halvorson et al., 2011, United States (6)	Literature review & CPG summary	N/A	Diagnosis and management of peripheral vascular trauma associated with long bone fractures and	Sequencing of vascular repair vs orthopedic fixation timing paradigms	Delay >8 hours elevates amputation rates up to 86%. Pooled data showed no statistical difference in amputation whether vascular or orthopaedic

				knee dislocations		repair was first (13% vs 11.6%). Post-repair bone manipulation did not increase graft disruption.
7	Parmaksizoglu et al., 2010, Turkey (7)	Case series (Retrospective analysis)	13 patients (5 below-knee amputations, 8 Type IIIC open fractures)	Patients under 50 years with complete loss of distal perfusion treated with emergency debridement, acute shortening, and vascular repair	Early structural lengthening (post-soft tissue healing, n=8) vs Delayed lengthening (post-fracture union, n=5)	Bone defects were fully restored in all patients; all achieved Chen Grade II function. Early subperiosteal lengthening was completed faster with no traction injury or disadvantage to the repaired vascular structures
8	Cakir et al., 2005, Turkey (8)	Retrospective review	192 patients	Upper and lower limb fractures with concomitant vascular injury requiring repair over a 17-year period. Excluded: primary amputations	Vascular repair before bone stabilization (stable fractures) vs Bone fixation first (unstable fractures). Bone fixation preferred first in tibia	Overall limb salvage was 88%. No experience with temporary shunts
9	McHenry et al., 2002, United States (9)	Retrospective review	27 patients (5 orthopaedic intervention first, 22 revascularization first)	Isolated gunshot wounds requiring acute revascularization and fracture fixation (brachial, femoral, popliteal). Excluded: defects not	Fracture fixation followed by vascular repair (Group 1) vs Vascular repair first (Group 2) vs Temporary shunt first, then bone fixation, then definitive	Time to revascularization was significantly longer in Group 1 Group 1 had an 80% fasciotomy rate vs 36% in revascularization-first groups No iatrogenic disruptions of vascular repairs or shunts

				needing fixation	repair (Group 3)	occurred during subsequent fixation
10	Iannacone et al., 1994, United States (10)	Retrospective case series	6 patients (7 distal femoral fractures)	Distal femoral fractures with angiographically documented superficial femoral/popliteal artery injuries	Provisional external fixation followed by early primary exchange to an intramedullary nail	Average ischemia time was 5 hours. Temporary vascular shunts used in 2 cases (one pre- and one post-external fixation). No complications or disruptions related to vascular repairs occurred. 100% fracture union achieved
11	Schlickewei et al., 1992, Germany (11)	Retrospective review	113 patients	Combined upper and lower limb fractures with associated arterial injuries treated over an 18-year period	Evaluation of clinical prognostic parameters and timing on limb salvage outcomes	Primary amputation in 23 cases; secondary amputation in 27 cases. Of secondary amputations, 51.8% had ischemia >6 hours and 85.2% were type III open fractures. Fracture stabilized while harvesting vein graft; zero shunt experience

Section 3: Results summary write-up

The compiled evidence from the eleven studies included highlights a direct, time-dependent correlation between warm ischemia time and limb salvage success. Earlier studies have cohorts where temporary vascular shunts have not been utilized.(8,11) – among these, Schlickewei et al. reported that 51.8% of secondary amputations occurred when warm ischemia exceeded six hours, emphasizing that delays in restoring perfusion directly compromise skeletal muscle viability.

When primary bone fixation was prioritized over revascularization, significant structural delays may occur. Lewis et al. documented a mean time to revascularization of 9.5 hours in the fracture-first (PRE) group versus 5.8 hours in the revascularization-first (POST) group. This prolongation of tissue hypoxia independently predicted a near-tripling of extremity amputation rates (37% vs. 13%) and a higher incidence of acute graft failure (26% vs. 8%) and rhabdomyolysis.(4) Similarly, McHenry et al. observed that executing orthopaedic fixation before vascular repair resulted in an 80% fasciotomy rate compared to 36% when revascularization was performed first.(9) It may be pointed out however, that the type of fracture fixation has not been uniform across studies – and the evidence suggests that temporary external fixation should be preferred over definitive fixation/internal fixation to shorten the surgical time it takes to execute the skeletal stabilization, specially when the orthopaedic intervention is being carried out first.

Temporary intravascular shunting has been adopted in more recent studies. Shunt placement rapidly re-establishes distal arterial flow, effectively halting the ischemic cascade. Multiple series demonstrate that a "vessel-first" or "shunt-first" pathway achieves excellent long-term limb salvage rates, reaching 92% in select popliteal trauma cohorts.(5,10) Furthermore, Parmaksizoglu et al. established that early bone lengthening via callus distraction following initial acute shortening and immediate vascular repair safely accelerates structural recovery without introducing traction-related distress to healing anastomoses.(7)

More importantly, the clinical data thoroughly refutes the traditional concern that subsequent orthopaedic reduction and hardware manipulation risk iatrogenic disruption of an existing vascular repair or temporary shunt. Across multiple studies(4,9), there were no documented cases of mechanical shunt dislodgement or anastomotic tearing during subsequent bone stabilization. Additionally, Halvorson et al.'s pooled data confirmed no statistical difference in overall amputation rates whether definitive vascular or orthopaedic repair was performed first, provided a temporary shunt was utilized early to stop the ischemic clock.(6) The only cautionary note comes from Cakir et al. who recommend performing the bony fixation first in 'unstable' fracture – though this has not been accurately defined.(8) These aggregated findings support the international Delphi consensus led by Pfeifer et al., which mandates that restoring distal arterial flow via temporary shunting takes absolute priority over structural bone care when critical warm ischemia approaches six hours.(2)

Section 4: Discussion

The surgical management of concurrent long bone fractures and major arterial injuries represents a time-sensitive, multidisciplinary challenge where the urge to salvage the limb comes at the substantially high risk of subjecting the patient to a secondary amputation. The overriding clinical priority when dealing with a limb having compromised vascularity is the rapid re-establishment of distal tissue perfusion. The core dilemma addressed by this consensus statement revolves on the precise surgical sequence: whether skeletal stabilization by an orthopaedic intervention must precede vascular reconstruction to protect the conduit, or whether immediate revascularization via temporary shunting must take absolute priority to minimize warm ischemia time. The collective evidence from the reviewed literature indicates a mandate favouring the latter of the two.

The conventional rationale offered for the 'fracture-fixation first' approach is that manipulation of a severely displaced or comminuted fracture after a vascular repair risked placing excessive traction, shear forces, or torque on a freshly sutured vascular anastomosis, potentially precipitating immediate graft thrombosis or mechanical disruption. However, the data analyzed in this review indicate that this concern is largely theoretical and unsupported by clinical outcomes. This mechanical risk that comes from manipulating a limb is even less with a temporary vascular shunt is used rather than performing a vessel repair or reconstruction with a graft.

Conversely, the biological risk of delaying revascularization to perform primary bone fixation can be high – specially, when the orthopaedic intervention takes a long time. Skeletal stabilization, whether via plating, intramedullary nailing, or external fixation, is a demanding procedure that can consume hours of operative time. Accepting this delay routinely pushes the warm ischemia time far past the critical 6-hour threshold. The consequences of this delay are clearly delineated in the historical baseline studies(8,11), where temporary shunting was unavailable. Furthermore, Lewis et al. utilized multivariable logistic regression to confirm that fracture fixation prior to revascularization stands out as the single independent modifiable predictor for both acute graft failure and eventual limb loss.(4)

Placing a temporary shunt is an uncomplicated, rapid vascular procedure that can be accomplished in minutes. By executing shunting as the index intervention, the surgical team instantly stops the ischemia clock – buying time for the orthopaedic procedure to be carried out. Perfusion is maintained while the skeletal stabilization is being carried out safeguarding the viability of skeletal muscle and neural structures. Establishing a temporary shunt gives the orthopaedic surgeon an unhurried window to safely clean, debride, and temporarily stabilize the bone structures, which is most effectively achieved via rapid external fixation. External fixation prevents additional soft-tissue stripping and devascularization of collateral circulation that occurs during extensive internal fixation exposures. Jin et al. highlighted that using less-invasive temporary external framing provides exceptional baseline protection for hyper-acute arterial suture lines while keeping deep infection and pin-tract complications low.(3) Once the bone is stabilized at its proper anatomical length and alignment, the vascular surgeon can return to replace the temporary shunt with a definitive autologous vein graft. This precise sequencing ensures that the final vascular conduit is measured accurately against a stable skeletal length and alignment, completely eliminating the risk of a graft being constructed under excessive tension or with redundant kinking that invites thrombosis.

This staged damage-control principle is further validated by Iannacone et al., who successfully proved that early primary external fixation acted as a safe, definitive bridge to subsequent intramedullary nailing once the soft-tissue and vascular structures had completely stabilized.(10) Parmaksizoglu et al. expanded the safety of early mechanical staging by demonstrating that subperiosteal callus distraction for structural bone lengthening can safely occur concurrently with fracture healing soon after soft-tissue closure, without posing a risk of traction-induced thrombosis or breakdown of the vascular construct.(7)

To summarize, the practice of delaying revascularization to achieve rigid bone fixation introduces an unacceptable ischemic penalty that severely compromises limb survival. Based on the literature analyzed, the most effective strategy or surgical sequence appears to be: temporary vascular shunting, debridement and rapid external fixation, definitive vascular repair or reconstruction with a graft and delayed definitive fracture fixation after healing of the soft tissues – following this sequence can minimize warm ischemia, reduce compartment syndrome, and maximize long-term limb salvage in complex extremity trauma involving vascular injuries.

Section 5: Risk of bias of included studies

Study	**Confounding/ selection**	**Exposure/ intervention**	**Missing data**	**Outcome measurement**	**Selective reporting**	**Overall**
Castro 2025	Serious	Moderate	Low	Low	Low	Moderate Risk

Study	Confounding/ selection	Exposure/ intervention	Missing data	Outcome measurement	Selective reporting	Overall
Pfeifer 2024	Low	Low	Low	Low	Low	Low Risk
Jin 2022	Serious	Moderate	Low	Low	Low	Moderate Risk
Lewis 2022	Serious	Low	Low	Low	Low	Moderate Risk
Fairhurst 2018	Serious	Serious	Low	Serious	Low	Moderate Risk
Tunali 2016	Serious	Serious	Serious	Low	Low	Moderate Risk
Parmaksizoglu 2010	Serious	Serious	Low	Moderate	Low	Moderate Risk
Cakir 2005	Serious	Serious	Low	Low	Low	Moderate Risk
McHenry 2002	Serious	Serious	Serious	Low	Low	High Risk
Iannacone 1994	Serious	Serious	Low	Low	Low	Moderate Risk
Schlickewei 1992	Serious	Serious	Serious	Low	Low	High Risk

Section 5: Response/Recommendation

Temporary vascular shunting should be performed prior to bone fixation in extremities approaching or exceeding critical warm ischemia times (>6 hours) to immediately restore distal perfusion, followed safely by provisional skeletal stabilization and delayed definitive vascular repair.

Section 6: Level/ strength of Evidence

MODERATE – While the evidence is consistent across multiple studies, most of the included studies are retrospective case series/cohort studies, many of them lacking comparison groups. Temporary vascular shunting has been utilized only by a subset of these studies and the type of fracture fixation also varies. However, the magnitude of effect is large which is reflected in the reduction of rates of secondary amputation, which in for this question should be taken as the primary outcome measure of interest. This is also supported by the recommendations made in the recent international multidisciplinary Delphi consensus process.

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