RQ1. Does the use of a pneumatic tourniquet reduce blood loss and improve the quality of debridement in trauma patients?

Background

Pneumatic tourniquets are commonly used in extremity trauma surgery to provide a bloodless field, improve visualization, and reduce intraoperative blood loss. While these advantages may theoretically facilitate debridement, tourniquet-induced ischemia can impair assessment of tissue viability by masking bleeding characteristics. Current orthoplastic guidelines recommend reassessing tissue viability after tourniquet release before definitive wound closure.

Results Summary

Thirteen studies were included, comprising two systematic reviews/meta-analyses, one randomized trial, and multiple cohort studies. Evidence consistently demonstrated reduced blood loss, improved operative visualization, and shorter operative time with tourniquet use. However, no study directly evaluated debridement quality, completeness of tissue excision, or residual contamination. The largest trauma-specific study (FLOW trial secondary analysis) found no overall increase in complications.

Risk of Bias

Moderate risk of bias. Most included studies were retrospective observational cohorts, with only one randomized clinical trial. There was substantial heterogeneity in fracture severity, patient populations, surgical techniques, and outcome measures. Importantly, most studies assessed surrogate outcomes (blood loss, operative time, complications) rather than direct measures of debridement quality.

Recommendation

A pneumatic tourniquet may be used selectively during extremity trauma surgery to reduce blood loss and improve visualization. In severe open fractures, particularly Gustilo III injuries, the tourniquet should be released before final assessment of tissue viability, completion of debridement, and wound closure.

Strength of Evidence

Moderate. The evidence includes Level I systematic reviews, one randomized trial, large cohort studies, and supporting orthoplastic guidelines. There is consistent evidence for reduced blood loss and improved visualization, but evidence is insufficient to conclude that tourniquet use improves debridement quality because no study directly assessed this outcome.

Section 1: Background

Pneumatic tourniquets are frequently used during extremity trauma surgery to create a bloodless surgical field, improve visualization, facilitate fracture fixation, and reduce intraoperative blood loss. Their role in open-fracture debridement remains controversial. While improved visualization may theoretically enhance the accuracy of debridement and identification of foreign material, tourniquet-induced ischemia may impair assessment of tissue viability by obscuring bleeding characteristics, which are essential during evaluation of muscle and soft-tissue viability.

Current orthopaedic trauma and orthoplastic literature consistently demonstrates reduced blood loss and improved operative visualization with tourniquet use. However, direct evidence evaluating completeness or quality of debridement is lacking. Most studies assess infection rates, wound complications, operative time, postoperative pain, reoperation rates, and wound healing rather than objective debridement outcomes.

Orthoplastic guidelines including BOA/BAPRAS and AO Trauma emphasize meticulous debridement and recommend reassessment of tissue viability following tourniquet release before definitive wound closure. Therefore, current evidence supports selective use of tourniquets as an adjunct to trauma surgery but does not conclusively demonstrate improvement in debridement quality.

Section 2: Data Extraction Table

S. No	Author, Year, Country	Study Design	Sample Size	Study Population (Inclusion/Exclusion)	Groups Compared	Follow-up	Results
1	Gitajn IL et al., 2021, USA	Retrospective cohort; secondary analysis of FLOW trial	1351 open fractures	Adults undergoing surgical treatment of open lower-extremity fractures	Tourniquet vs No Tourniquet	FLOW trial follow-up	No overall increase in complications. Gustilo IIIA and IIIB fractures demonstrated increased odds of unplanned reoperation with tourniquet use.
2	Benedick A et al., 2020, USA	Retrospective comparative cohort	903 ankle fractures	Operatively treated OTA 44B/44C ankle fractures	Tourniquet vs No Tourniquet	Mean 47.6 weeks	No significant differences in superficial

S. No	Author, Year, Country	Study Design	Sample Size	Study Population (Inclusion/Exclusion)	Groups Compared	Follow-up	Results
							infection, deep infection, or wound-healing complications.
3	Mahmoudirad G et al., 2016, Iran	Randomized clinical trial	40 tibial fractures	Patients undergoing tibial fracture plating	Tourniquet release before closure vs after closure	Early postoperative follow-up	Earlier release improved assessment of bleeding and wound condition.
4	Farhan-Alanie MM et al., 2021	Systematic review and meta-analysis	552 procedures (6 RCTs)	Lower-limb fracture surgery	Tourniquet vs No Tourniquet	Variable	Reduced blood loss and operative time; insufficient evidence regarding complications.
5	Præstegaard M et al., 2019	Systematic review and meta-analysis	Multiple lower-limb fracture studies	Adult lower-limb fracture fixation surgery	Tourniquet vs No Tourniquet	Variable	Improved visualization and shorter operative duration; evidence insufficient for clinical superiority.
6	Konrad G et al., 2005, Germany	Prospective comparative study	69 patients	Operative ankle fractures	Tourniquet vs No Tourniquet	Postoperative follow-up	Increased postoperative swelling and pain in the tourniquet group.
7	El-Khaldi I et al., 2024	Retrospective cohort	Ankle fracture cohort	Operatively treated ankle fractures	Tourniquet vs No Tourniquet	Minimum 1 year	No significant difference in reoperation rates.

S. No	Author, Year, Country	Study Design	Sample Size	Study Population (Inclusion/Exclusion)	Groups Compared	Follow-up	Results
8	Sim J et al., 2019	Retrospective cohort	Ankle fracture cohort	Operatively treated ankle fractures	Tourniquet vs No Tourniquet	Institutional follow-up	No major differences in clinical outcomes.
9	Cifaldi A et al., 2023	Comparative cohort	Ankle fracture cohort	Anterior ankle fracture fixation surgery	Tourniquet vs No Tourniquet	Postoperative follow-up	No significant increase in wound complications.
10	Lichte P et al., 2024	Prospective clinical study	Limb surgery patients	Patients undergoing limb surgery with tourniquet application	Pre- vs Post-tourniquet microcirculation	Postoperative wound assessment	Reduced deep microcirculation but no adverse effect on wound healing.
11	Kragh JF Jr et al., 2008, USA	Prospective observational military study	232 casualties (428 tourniquets)	Combat extremity trauma	Emergency tourniquet application	Median 7 days	Effective hemorrhage control; no limb loss attributable to tourniquet use. Indirect evidence only.
12	Burns TC et al., 2012, USA	Retrospective combat trauma cohort	213 Gustilo III open tibial fractures	Severe combat-related open tibial fractures	Infection and limb outcome analysis	Mean 24 months	Deep infection strongly associated with amputation. Tourniquet effect not directly evaluated.
13	Pasquier P et al., 2012, France	Commentary and literature review	Not applicable	Severe open tibial fractures	Literature review	Not applicable	Raised concerns regarding tissue ischemia and

S. No	Author, Year, Country	Study Design	Sample Size	Study Population (Inclusion/Exclusion)	Groups Compared	Follow-up	Results
							potential long-term complications. Indirect evidence only.

Supporting Orthoplastic and Guideline Evidence (Narrative Evidence)

Reference	Key Recommendation Relevant to the Research Question
BOA/BAPRAS Standards for Open Fractures (2020)	Recommends reassessment of tissue viability after tourniquet release before definitive wound closure.
Nanchahal et al. Standards for Management of Open Fractures (2009)	Radical debridement remains the most important determinant of infection prevention and limb salvage.
AO Trauma Principles of Open Fracture Management	Tissue viability should be assessed after reperfusion using colour, consistency, contractility, and bleeding characteristics.
Khan et al., 2007	Accurate assessment of tissue viability is essential in severe open injuries and should not rely solely on a bloodless field.
Trickett et al., 2015	Supports reassessment of tissue perfusion and viability after tourniquet release.
Loh et al., 2021	Reinforces orthoplastic principles of meticulous debridement and viability assessment.

Table Footnote

Important limitation: No study included in this review directly measured debridement quality, completeness of tissue excision, residual contamination, surgeon-assessed adequacy of debridement, or repeat debridement attributable to inadequate initial excision. Therefore, conclusions regarding debridement quality are indirect and based primarily on surrogate outcomes such as blood loss, visualization, wound complications, and reoperation rates.

Level of Evidence by Included Study

Study	Level of Evidence
Farhan-Alanie et al.	Level I

Study	Level of Evidence
Præstegaard et al.	Level I
Mahmoudirad et al.	Level II
Gitajn et al.	Level III
Benedick et al.	Level III
Konrad et al.	Level II–III
El-Khaldi et al.	Level III
Sim et al.	Level III
Cifaldi et al.	Level III
Lichte et al.	Level III
Kragh et al.	Level III
Burns et al.	Level III
Pasquier et al.	Level V

Section 3: Results Summary

A total of 13 studies were included in the evidence synthesis, comprising two systematic reviews and meta-analyses, one randomized clinical trial, several retrospective and prospective cohort studies, and supporting trauma literature. The highest-quality evidence originated from the systematic reviews by Farhan-Alanie et al. and Præstegaard et al., which demonstrated reduced intraoperative blood loss, improved operative visualization, and shorter operative duration with tourniquet use during lower-limb fracture surgery. However, neither review demonstrated improvements in infection rates, wound healing, functional outcomes, or debridement quality.

The largest trauma-specific study, a secondary analysis of the FLOW trial by Gitajn et al., evaluated 1351 open fractures and found no overall increase in complications associated with tourniquet use. However, patients with Gustilo IIIA and IIIB fractures demonstrated increased odds of unplanned reoperation. Benedick et al. reported no significant differences in superficial infection, deep infection, or wound-healing complications among 903 operatively treated ankle fractures.

Mahmoudirad et al. demonstrated that release of the tourniquet before wound closure improved assessment of bleeding and tissue condition. Konrad et al. reported increased postoperative swelling and pain in patients undergoing ankle fracture fixation with tourniquet use. More recent ankle fracture studies similarly found no significant differences in reoperation rates or wound complications between tourniquet and non-tourniquet groups.

Importantly, none of the included studies directly assessed completeness of debridement, adequacy of tissue excision, residual contamination, surgeon-assessed debridement quality, or repeat debridement attributable to inadequate initial debridement. Consequently, any relationship between improved visualization and improved debridement quality remains theoretical rather than evidence-based.

Section 4: Discussion

The principal benefit of pneumatic tourniquet use during extremity trauma surgery is the creation of a bloodless operative field, resulting in improved visualization and reduced intraoperative blood loss. These findings are consistently supported across systematic reviews, observational studies, and trauma literature. Improved visualization may facilitate fracture reduction, fixation, and soft-tissue procedures and may contribute to shorter operative duration.

Despite these advantages, the current evidence does not demonstrate that tourniquet use improves the quality or completeness of debridement. This distinction is important because debridement quality is determined not by visualization alone but by accurate identification and excision of non-viable tissue.

Orthoplastic principles emphasize assessment of tissue viability using clinical indicators such as colour, consistency, contractility, and bleeding characteristics. Because tourniquet inflation eliminates tissue bleeding, viability assessment may be impaired, particularly in severe open fractures with extensive soft-tissue injury. Consequently, concerns remain that prolonged tourniquet use could lead to underestimation of the zone of injury and inadequate excision of marginally viable tissue.

The FLOW trial secondary analysis provides the most relevant trauma-specific evidence. Although overall complication rates were not increased, severe Gustilo IIIA and IIIB injuries demonstrated higher odds of unplanned reoperation when a tourniquet was used. While causality cannot be established, these findings support caution when applying tourniquets in heavily contaminated or severely injured limbs.

Supporting orthoplastic guidance from BOA/BAPRAS, AO Trauma, and Nanchahal et al. consistently recommends reassessment of tissue viability after restoration of perfusion. These recommendations are based on the principle that accurate assessment of muscle viability and soft-tissue perfusion requires evaluation in a reperfused limb. Therefore, while a tourniquet may be used to facilitate exposure and reduce blood loss, final assessment of tissue viability should occur following tourniquet release.

Overall, the available literature supports tourniquet use as an adjunct that improves operative conditions but does not provide evidence that it improves debridement quality.

Section 5: Risk of Bias

Overall Risk of Bias: MODERATE

Justification:

• Most primary studies were retrospective observational cohorts.

• Only one randomized clinical trial was identified.

• Considerable heterogeneity exists in patient populations, fracture severity, surgical techniques, and outcome measures.

• Most studies evaluated surrogate outcomes such as blood loss, operative time, infection, wound complications, or reoperation rates rather than debridement quality.

• No included study directly measured completeness of debridement, residual contamination, adequacy of tissue excision, or surgeon-assessed debridement quality.

• Findings regarding blood loss reduction and improved visualization were generally consistent across studies.

Section 6: Response / Recommendation

Recommendation:

A pneumatic tourniquet may be used selectively during extremity trauma surgery to reduce blood loss and improve operative visualization. Current evidence supports these benefits but does not demonstrate improvement in the quality or completeness of debridement. In severe open fractures, particularly Gustilo III injuries, the tourniquet should be released before definitive assessment of tissue viability, completion of debridement, and wound closure to permit accurate evaluation of perfusion and haemostasis.

Section 7: Level / Strength of Evidence

MODERATE

Justification:

The evidence base includes two systematic reviews and meta-analyses, one randomized clinical trial, large retrospective cohort studies, and supporting orthoplastic guidelines. There is consistent evidence that pneumatic tourniquets reduce blood loss and improve operative visualization. However, no study directly evaluated debridement quality or completeness of tissue excision. Therefore, the strength of evidence is moderate for blood loss reduction and visualization, but low for any conclusion regarding improvement in debridement quality.

References

1. Gitajn IL, Konda SR, Gage MJ, et al. Effect of Tourniquet Use During Surgical Treatment of Open Fractures: A Secondary Analysis of the FLOW Trial. *J Bone Joint Surg Am*. 2021;103(8):699–706.

2. Benedick A, Rivera T, Vallier HA. Effect of Tourniquet Use During Ankle Fracture Fixation on Wound Healing and Infectious Complications. *Foot Ankle Int*. 2020;41(7):787–794.
3. Mahmoudirad G, Bahador R, Khodabakhshi M. The Impact of Tourniquet Release Time on Wound Healing in Patients Undergoing Tibial Fracture Plating Surgery. *Mod Care J*. 2016;13(2):e5816.
4. Farhan-Alanie MM, Dhaif F, Trompeter A, Pearse M. The Risks Associated with Tourniquet Use in Lower Limb Trauma Surgery: A Systematic Review and Meta-analysis. *Eur J Orthop Surg Traumatol*. 2021;31(4):633–645.
5. Præstegaard M, Rasmussen S, Zobbe K, Holm G. Tourniquet Use in Lower Limb Fracture Surgery: A Systematic Review and Meta-analysis. *Injury*. 2019;50(3):527–535.
6. Konrad G, Markmiller M, Lenich A, Mayr E, Rüter A. Tourniquets May Increase Postoperative Swelling and Pain After Internal Fixation of Ankle Fractures. *J Orthop Trauma*. 2005;19(1):49–52.
7. El-Khaldi I, et al. Tourniquet Use During Ankle Fracture Fixation and Reoperation Risk. *Bone Joint Open*. 2024.
8. Sim J, Lee S, Kim J, et al. Clinical Outcomes of Tourniquet Use During Open Reduction and Internal Fixation of Ankle Fractures. *J Foot Ankle Surg*. 2019.
9. Cifaldi A, et al. Tourniquet Use and Wound Complications Following Ankle Fracture Surgery. *J Foot Ankle Surg*. 2023.
10. Lichte P, Kobbe P, Fischer H, et al. Intraoperative Pneumatic Tourniquet Application Reduces Deep Microcirculation Without Affecting Postoperative Wound Healing. 2024.
11. Kragh JF Jr, Walters TJ, Baer DG, et al. Practical Use of Emergency Tourniquets to Stop Bleeding in Major Limb Trauma. *J Trauma*. 2008;64(Suppl):S38–S49.
12. Burns TC, Stinner DJ, Mack AW, et al. Microbiology and Injury Characteristics in Severe Open Tibia Fractures from Combat. *J Trauma Acute Care Surg*. 2012;72(4):1062–1067.
13. Pasquier P, Renner J, Mérat S. Infections and Tourniquet Application in Severe Open Tibia Fractures from Combat. *J Trauma Acute Care Surg*. 2012;73(6):1627–1628.

Supporting Orthoplastic Evidence

14. British Orthopaedic Association, British Association of Plastic Reconstructive and Aesthetic Surgeons. *BOAST 4: Standards for the Management of Open Fractures*. London: BOA/BAPRAS; 2020.
15. Nanchahal J, Nayagam S, Khan U, Moran C, Barrett S, Sanderson F, et al. *Standards for the Management of Open Fractures of the Lower Limb*. London: Royal Society of Medicine Press; 2009.
16. AO Trauma Foundation. *AO Principles of Open Fracture Management*. AO Surgery Reference.
17. Khan U, Smitham P, Pearse M, Nanchahal J. Management of Severe Open Ankle Injuries. *Plast Reconstr Surg*. 2007;119(2):611–620.
18. Trickett RW, Rahman S, Page P, Pallister I. From Guidelines to Standards of Care for Open Tibial Fractures. *Ann R Coll Surg Engl*. 2015;97(6):469–475.
19. Loh B, Khatri C, Joseph N. Perioperative Management of Open Lower Limb Fractures: Current Concepts in Orthoplastic Care. *EFORT Open Rev*. 2021.