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# ICM on Open Injuries - Submission of the Consensus Recommendation

**RQ: Can existing open injury classification systems be reliably extrapolated to upper limb injuries?**

## Section 1: Background

Open injury classification systems are used to communicate injury severity, guide early management, predict complications and compare outcomes. However, most widely used systems were developed from lower-limb open fracture experience, particularly tibial trauma, where infection, nonunion, flap requirement and amputation are dominant endpoints [1,2,4]. Upper-limb injuries differ biologically and functionally: muscle bulk is less, collateral circulation is better, the tolerable ischemic interval may be longer than in the leg, and the final value of salvage is strongly influenced by hand sensibility, nerve integrity, tendon loss, joint stiffness and potential for reconstruction [1,5,6]. Also, from a functional standpoint the demands of the upper limb vary when compared to the lowerlimb. Therefore, a classification that predicts amputation or infection in the lower limb may not adequately predict upper-limb function or guide limb salvage decisions.

The uploaded studies include direct upper-limb evidence questioning the validity of MESS in upper-limb vascular trauma, mixed upper/lower extremity data suggesting that infection risk is driven by muscle injury, contamination and local circulation, upper-extremity agricultural trauma data showing increasing infection with injury severity, and OTA-OFC data suggesting better outcome prediction than Gustilo-Anderson in open long-bone fractures [1-4]. Additional nerve-outcome studies show that nerve type, delay to repair, patient age and objective peripheral nerve assessment strongly influence upper-limb function, variables that are not adequately represented in conventional open fracture scores [5,6].

## Section 2: Data extraction table

| S.no | Author, year, country | Study design | Sample size | Study population | Classification / comparator | Results and relevance to RQ |
|---|---|---|---|---|---|---|
| 1 | Togawa et al., 2005, Japan [1] | Small retrospective case series evaluating MESS in upper-limb major vascular injuries. | 3 patients with upper-limb vascular injuries and MESS >=7, identified from 5 upper-limb arterial injuries among 1024 trauma patients. | Severe upper-limb crush/trapping injuries with arterial injury; MESS 7-11. | MESS threshold >=7, traditionally used to support amputation in lower-limb trauma, compared with actual salvage/amputation outcome. | Two of three limbs with MESS >=7 were salvaged despite scores of 7 and 11. Authors concluded that MESS >=7 is not an appropriate sole indication for amputation in upper-limb major vascular injury. This directly argues against unmodified extrapolation of lower-limb salvage scores to the upper limb. |
| 2 | Yokoyama et al., 2008/2009, Japan [2] | Retrospective development and re-scoring study based on HFS-98 elements. | 394 open upper/lower extremity fractures initially; 352 fractures in infection analysis: humerus 27, forearm 62, femur 76, tibia 187. | Open fractures of humerus, forearm, femur and tibia. Amputations/deaths/lost follow-up excluded from infection analysis. | HFS-98-derived variables; new score using muscle injury, wound contamination and local circulation, each 0-20 points. | Muscle injury, wound contamination and local circulation predicted deep infection (all P=0.0001). Cutoff >=35 predicted infection with sensitivity 0.67, specificity 0.92, PPV 0.66 and NPV 0.98. Supports anatomically descriptive scoring across extremities, but upper-limb-specific validation remains limited. |
| 3 | Ali et al., 2008, USA [3] | Retrospective prognostic cohort of open agricultural upper-extremity injuries. | 214 patients: type 1 n=26, type 2 n=94, type 3 n=94. | Open agricultural upper-extremity injuries treated at a Midwestern Level I hospital; injuries ranged from lacerations to contaminated mutilating trauma. | Three-tier upper-extremity injury severity scheme, a modification of Gustilo-Anderson based on wound/soft-tissue damage, vascular compromise and contamination. | Forty patients developed infection: 17 superficial, 16 deep soft tissue and 7 osteomyelitis; 6 required amputation due to infection. Infection occurred in 2 type 1, 14 type 2 and 24 type 3 injuries (P=.07). The risk of infection broadly tracked injury severity, supporting upper-limb-specific severity grading. |
| 4 | Hao et al., 2016, USA / Republic of Korea [4] | Retrospective observational cohort comparing Gustilo-Anderson with OTA-OFC. | 512 adult patients with open long-bone fractures; 19 amputations, including 3 upper-extremity amputations. | Consecutive adult open long-bone fractures treated operatively at a Level I trauma centre; minimum 3-month follow-up. | Gustilo-Anderson versus OTA-OFC summative score, including skin, muscle, arterial injury, contamination and bone loss. | Gustilo-Anderson did not correlate with amputation, infection or soft-tissue coverage. OTA-OFC scores differed significantly for amputation, infection and soft-tissue coverage groups. Skin injury predicted amputation (OR 5.44), and score >=10 predicted amputation with sensitivity 79% and specificity 94%. OTA-OFC is promising but not fully validated as an upper-limb-specific score. |
| 5 | Czarnecki et al., 2020, Poland [5] | Retrospective outcome analysis after median/ulnar nerve reconstruction. | 41 patients: median nerve n=18, ulnar nerve n=15, both nerves n=8; mean follow-up 5 years. | Median and/or ulnar nerve injuries at middle/distal forearm level; complete nerve continuity loss reconstructed with end-to-end repair or autologous graft. | Functional outcomes by MRC sensory/motor recovery and DASH; prognostic factors including age and delay to repair. | Shorter delay from injury to repair correlated with better DASH score (P=0.0197), younger age correlated with better DASH (P=0.0140), and median nerve motor recovery was superior to ulnar/both nerves (83% vs 27%/25%; P=0.001). Shows that upper-limb outcome prediction requires nerve/function variables not captured by standard open-fracture scores. |
| 6 | Tang et al., 2020, China [6] | Diagnostic feasibility study | 7 male patients with unilateral | Traumatic upper-limb median, ulnar | Surface EMG-based quantitative | The method showed sensitivity 81.82%, specificity 98.90%, PPV 90%, NPV |

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| S.no | Author, year, country | Study design | Sample size | Study population | Classification / comparator | Results and relevance to RQ |
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| | | using surface EMG and machine learning for traumatic upper-limb peripheral nerve injury. | traumatic upper-limb PNI plus 10 healthy male controls; 34 arms tested. | or radial nerve injuries, at least 6 months from injury, wounds healed and stable. | nerve assessment compared with routine clinical/electrophysiological assessment. | 97.83%, and significant correlation with clinical assessment. Indirectly supports the need for quantitative nerve assessment as a complement to open injury classification in the upper limb. |

## Section 3: Results summary

Six uploaded studies were reviewed. The most direct upper-limb evidence comes from Togawa et al., who evaluated MESS in severe upper-limb vascular trauma and found that two limbs with MESS >=7 were successfully salvaged, including one with a score of 11 [1]. Because MESS was derived from lower-limb trauma and doubles ischemia points after 6 hours, the study emphasized that upper-limb collateral circulation, lower muscle mass and longer tolerable ischemia make this threshold unsuitable as a sole amputation trigger in upper-limb injuries.

Yokoyama et al. developed an HFS-98-derived infection prediction score in mixed upper and lower extremity open fractures. Muscle injury, wound contamination and local circulation were the independent predictors of deep infection, and a score >=35 had high specificity and negative predictive value [2]. This supports the importance of tissue- and circulation-based scoring rather than broad anatomic extrapolation, although subgroup validation for humerus and forearm fractures was not separately established.

Ali et al. evaluated 214 open agricultural upper-extremity injuries using a three-tier severity scheme modified from Gustilo-Anderson. Infection increased from type 1 to type 3 injuries, with 40 total infections and 6 amputations due to infection [3]. This suggests that upper-limb-specific grading can stratify infection risk, particularly when contamination and vascular compromise are prominent.

Hao et al. found OTA-OFC superior to Gustilo-Anderson for predicting amputation, infection and soft-tissue coverage in open long-bone fractures, with score >=10 predicting amputation with 79% sensitivity and 94% specificity [4]. However, only 3 amputations were upper-extremity amputations, so extrapolation to upper-limb-specific decision-making remains uncertain. Czarnecki et al. and Tang et al. show that nerve injury, repair timing and quantitative nerve assessment are central determinants of upper-limb function [5,6].

## Section 4: Discussion

The available evidence does not support reliable, unmodified extrapolation of existing open injury classification systems to upper-limb injuries. The central problem is that many conventional systems were designed around lower-limb endpoints. For the lower limb, infection, nonunion, soft-tissue coverage and amputation often dominate decision-making. In the upper limb, these outcomes remain important, but the clinical value of salvage is also determined by sensibility, intrinsic muscle function, tendon continuity, joint mobility, nerve recovery, hand dominance, occupation and reconstructive potential.

The strongest cautionary evidence is provided by Togawa et al. The MESS threshold of >=7 has historically been used to support amputation, but two upper limbs with MESS >=7 were salvaged successfully. The authors explained why a lower-limb ischemia-based score may overestimate amputation risk in the arm: upper-limb muscle mass is smaller, collateral circulation is richer, and the tolerable ischemic interval may be longer than the six-hour threshold used for the leg [1]. Therefore, MESS should not be used as a stand-alone decision tool for amputation in upper-limb trauma.

The Gustilo-Anderson classification is useful for communication and broad infection risk stratification, but its reliability and prognostic performance are limited. In Hao et al., Gustilo-Anderson did not correlate with amputation, infection or need for soft-tissue coverage, whereas OTA-OFC performed better [4]. Ali et al. similarly required a modified upper-extremity scheme to describe agricultural injuries, suggesting that standard long-bone fracture classifications may not capture the unique contamination and soft-tissue patterns seen in hand and forearm injuries [3].

More descriptive systems appear more promising. Yokoyama et al. identified muscle injury, wound contamination and local circulation as the key predictors of deep infection in open extremity fractures [2]. These variables are biologically plausible in both upper and lower limbs. OTA-OFC similarly captures skin, muscle, arterial injury, contamination and bone loss [4]. Such component-based systems may be more transferable than simple lower-limb-derived grade systems. However, the evidence does not yet establish reliable upper-limb-specific thresholds for salvage, infection, function or amputation.

A major limitation of applying current open fracture classifications to the upper limb is inadequate representation of nerve injury and hand function. Czarnecki et al. showed that age, delay to nerve repair and the injured nerve influence final DASH and motor outcomes, while Tang et al. demonstrated the feasibility of quantitative assessment of traumatic upper-limb nerve injury [5,6]. These data are not open fracture

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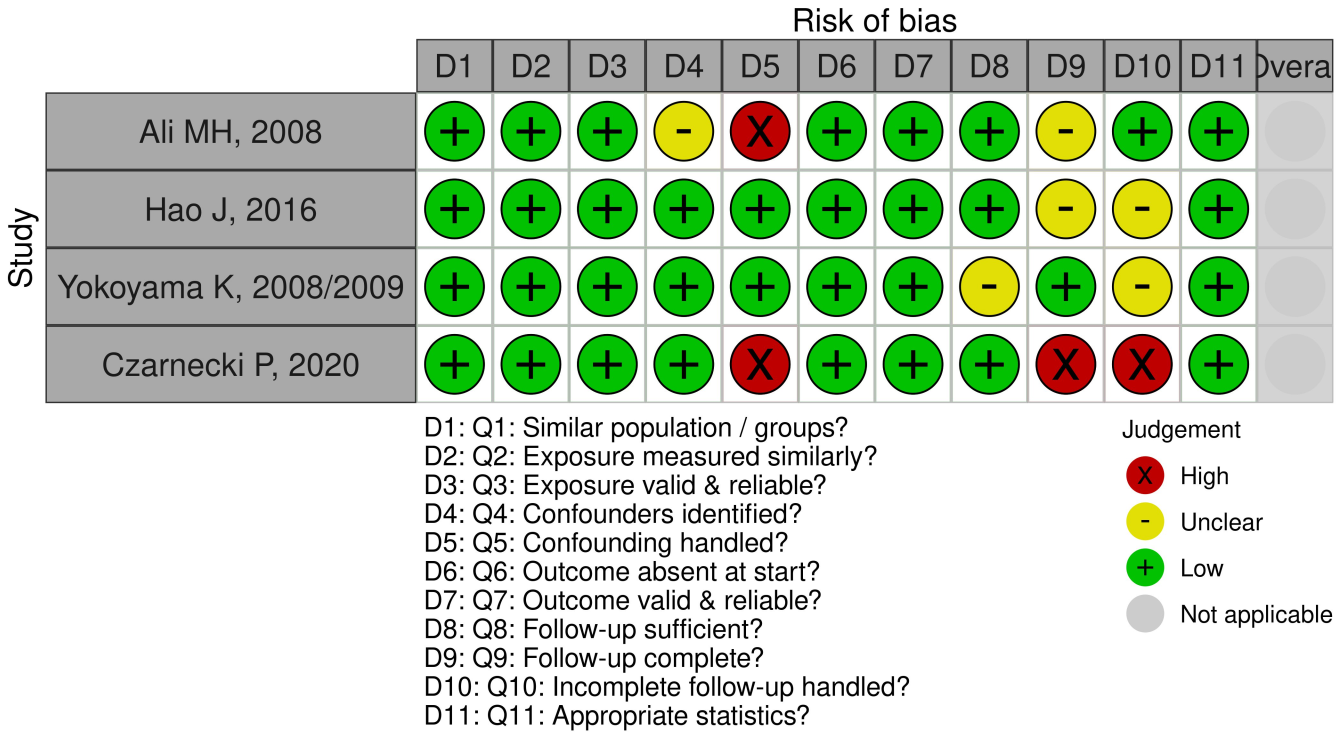
classification studies, but they reinforce a crucial principle: an upper-limb classification must incorporate nerve/tendon/function-related variables if it is expected to predict meaningful outcomes rather than only infection or amputation.

Therefore, existing systems can be used cautiously for structured description of the injury and communication between teams. They should not be directly extrapolated to make definitive upper-limb salvage or amputation decisions. A reliable upper-limb system should include conventional open injury components (wound size, contamination, muscle injury, bone loss and local circulation) plus upper-limb-specific variables: major nerve injury, tendon/muscle loss, hand perfusion, ischemia duration, joint involvement, reconstructability, sensibility, dominance, patient occupation and expected functional recovery. Until such a system is prospectively validated, decisions should remain individualized and multidisciplinary.

## Section 5: Risk of bias of included studies

## Retrospective COHORT STUDIES




## Case series study

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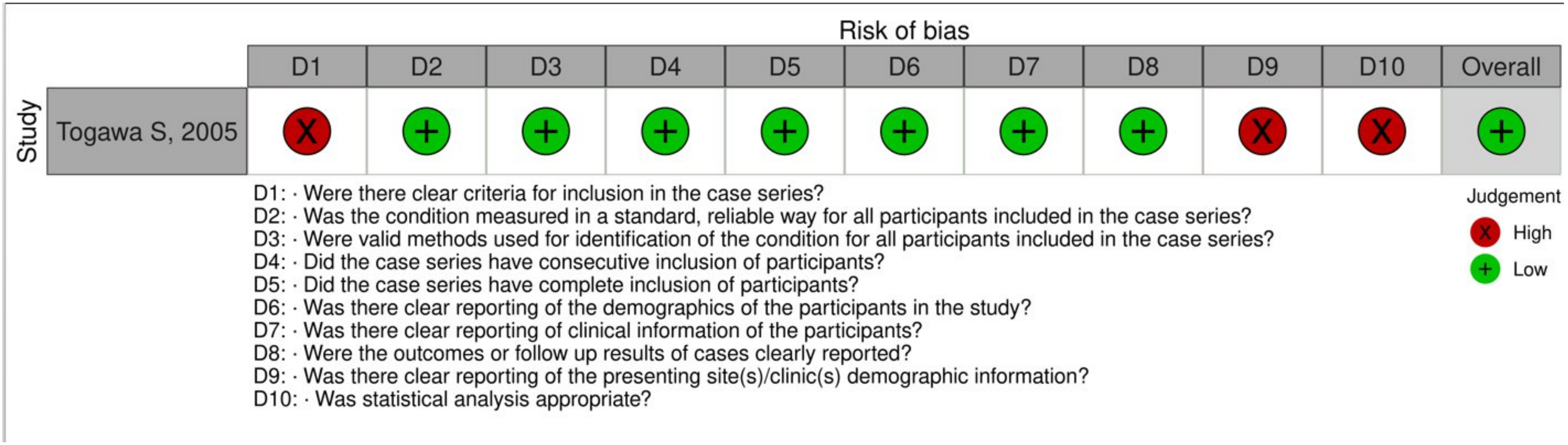
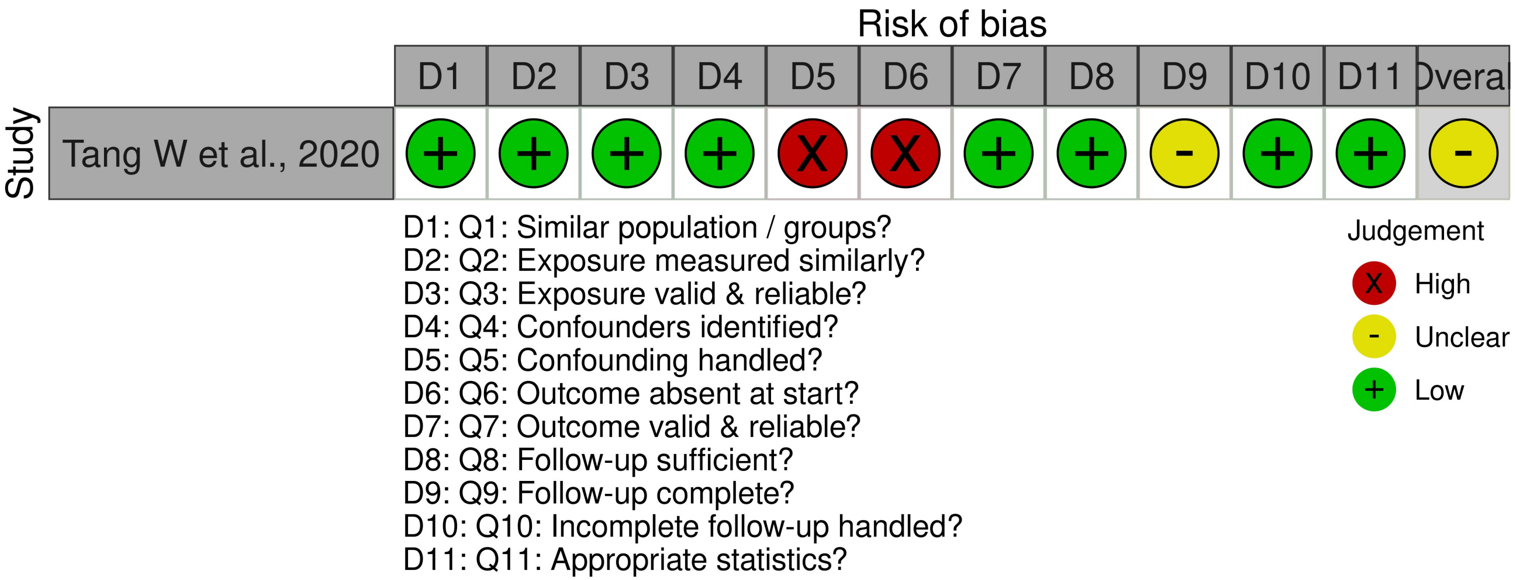



## Cross sectional analytical study



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## Section 5: Response / Recommendation

**Existing open injury classification systems should NOT be extrapolated to upper-limb injuries without modification and upper-limb-specific validation. Gustilo-Anderson, OTA-OFC or HFS-derived scores may be used for structured description and broad risk stratification, but salvage/amputation decisions in upper-limb injuries should incorporate nerve injury, tendon/muscle loss, vascularity, contamination, reconstructability and expected hand function, and should be made by a multidisciplinary team.**

## Section 6: Level / strength of Evidence

LOW. The evidence consists mainly of retrospective cohorts and small case series, with only limited direct upper-limb validation of existing classification systems. The most direct study on MESS is a small case series, while larger studies either combine upper and lower extremity fractures or focus on open long-bone outcomes rather than upper-limb function. The recommendation is therefore based on low-level but consistent evidence, supported by strong anatomical and functional rationale.

## References


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