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Ultrasound-guided carpal tunnel release by non-balloon blade, balloon-assisted blade or looped thread: a technique-stratified systematic review and meta-analysis of uncontrolled within-group outcomes

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ADMINISTRATIVE INFORMATION

Support - None.

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 2 September 2026 and was last updated on 24 September 2026.

INTRODUCTION

Review question / Objective To describe technique-specific outcomes and safety among adults with carpal tunnel syndrome undergoing percutaneous ultrasound-guided carpal tunnel release (UGCTR), stratified into three release groups defined by cutting principle and mechanical nerve protection: non-balloon blade release, balloon-assisted blade release and looped-thread release.

Rationale Ultrasound-guided carpal tunnel release (UGCTR) is increasingly performed as a minimally invasive alternative to open and mini-open release. UGCTR is not a single uniform procedure: release techniques differ in cutting principle, mechanical nerve protection, instrumentation and procedural workflow. Previous systematic reviews have

generally pooled UGCTR without technique stratification, which may obscure clinically relevant differences.

Condition being studied Carpal tunnel syndrome (CTS) is the most common compressive peripheral neuropathy, resulting from median nerve entrapment beneath the transverse carpal ligament. Patients experience hand pain, numbness, nocturnal paresthesia, and impaired function, which in severe cases can lead to irreversible axonal injury and thenar muscle atrophy.

METHODS

Search strategy A PubMed scoping search on 28 June 2026 and an initial three-database run on 1 September 2026, whose search strings were not

retained, were used to develop the strategy and for pilot screening before registration. The definitive search of PubMed, Embase and CINAHL (database inception to 5 September 2026) combined controlled vocabulary (MeSH/Emtree) and free-text terms for carpal tunnel syndrome, carpal tunnel release and ultrasound guidance with technique- and device-specific terms. Every report found eligible in the pilot screening was re-identified by the definitive search. Web of Science, listed in the original registration, was not searched and has been removed. No language restrictions were applied. Reference lists of included studies and previous systematic reviews were hand-searched.

Participant or population Adults (≥ 18 years) with a clinical diagnosis of carpal tunnel syndrome, with or without electrodiagnostic or sonographic confirmation.

Intervention Percutaneous real-time UGCTR, classified into three release groups by cutting principle (blade or thread) and mechanical nerve protection (no mechanical barrier, skid or balloon): non-balloon blade release, balloon-assisted blade release and looped-thread release. These groups contain the same pooled arms as the hook-knife, retractable-knife and thread categories of the original registration.

Comparator None required. Single-arm UGCTR cohorts and the UGCTR arms of comparative studies were analyzed as uncontrolled within-group (before–after) outcomes.

Study designs to be included Prospective and retrospective cohort studies, registry studies, randomized trials and single-arm case series enrolling at least five patients; comparative studies contribute their UGCTR arm only.

Eligibility criteria Inclusion: (1) adults aged ≥ 18 years with carpal tunnel syndrome; (2) percutaneous real-time UGCTR with a non-balloon blade, a balloon-assisted blade or a looped thread; (3) paired preoperative and postoperative BCTQ scores or extractable secondary outcomes; (4) at least five patients; (5) one of the study designs listed above. Exclusion: (1) case reports and series with fewer than five patients; (2) cadaveric or animal studies; (3) technical notes without clinical outcomes; (4) narrative reviews and conference abstracts without a full publication; (5) ultrasound-guided hydrodissection or hydrorelease without transection of the transverse carpal ligament; (6) reports with insufficient methodological detail for risk-of-bias assessment.

Information sources PubMed, Embase and CINAHL; reference lists of included studies and of previous systematic reviews.

Main outcome(s) Uncontrolled within-group improvement in the BCTQ Symptom Severity Scale (preoperative minus follow-up score) at the final follow-up within a 6–12-month window, benchmarked against an anchor-based MCID of 1.14 points. When more than one assessment fell within the window, the latest was used. When one cohort was reported more than once, the report with the most complete follow-up within the window was retained.

Additional outcome(s) BCTQ Functional Status Scale improvement (MCID 0.74 points); QuickDASH improvement; return-to-work time; and safety events. QuickDASH and return-to-work times were summarized descriptively and not pooled because follow-up times and summary statistics differed. Procedure duration, listed in the original registration, was not extracted or reported. Safety events were extracted per treated unit as reported. Seriousness was recorded as graded by the original investigators; no review-level seriousness grading was applied. Repeat release (for persistent or recurrent symptoms or incomplete division), surgical re-exploration for a complication and operations after post-procedure injury were recorded separately, and unplanned reoperation for any reason was tabulated as their sum.

Data management Records were deduplicated and screened at title/abstract and full-text level by two reviewers. For the 55 records new to the definitive search, an AI model drafted preliminary title-and-abstract judgements; each was reviewed and independently confirmed or overruled by two human reviewers, and no record was excluded on the AI draft alone. Data were extracted independently by two reviewers into a piloted spreadsheet.

Quality assessment / Risk of bias analysis Risk of bias was assessed with ROBINS-I across seven domains. The 11 reports that contributed to the primary meta-analysis and had no cohort-overlap questions were assessed independently by two reviewers; the remaining 14 reports were assessed by one reviewer and verified by the second. Certainty of evidence was rated with GRADE (added after registration).

Strategy of data synthesis Within-group change scores were pooled with random-effects models using restricted maximum-likelihood (REML)

estimation of between-study variance. Confidence intervals were calculated with the Hartung–Knapp–Sidik–Jonkman method (the confidence-interval method was not specified in the original registration). Ninety-five percent prediction intervals were added. Missing change-score standard deviations were imputed assuming a pre–post correlation of 0.50. Heterogeneity was quantified with Cochran's Q , I^2 and τ^2 . Funnel asymmetry was examined with funnel plots and Egger's regression and interpreted as small-study effects (added after registration).

Subgroup analysis By release group: non-balloon blade, balloon-assisted blade and looped thread. The groups were relabelled and redefined by cutting principle and mechanical nerve protection after registration, without moving any pooled arm between subgroups. Between-group differences were tested with the Knapp–Hartung F test in place of the registered subgroup Q test; Wald-type Q test results are reported alongside.

Sensitivity analysis As registered: (1) pre–post correlation of 0.25 and 0.75; (2) leave-one-out analysis. Cohort overlap: the Chern 2014/2015 overlap was resolved at study selection by excluding the Chern 2014 clinical dataset, so no retain-versus-exclude analysis was run for that family; the Kim 2024/Park 2022 overlap was implemented as a Park-for-Kim substitution in which the two Park arms were combined into one study estimate ($k = 13$), with bilateral-dependence scenarios, and the separate-arm ($k = 14$) and combined Kim-plus-Park ($k = 15$) calculations were retained as diagnostic outputs only. The registered short-term (1–4 weeks) versus final follow-up comparison was not completed because follow-up denominators and standard-error assumptions could not be resolved, and it is not reported. Added after registration: removal of the largest registry, exclusion of the hemodialysis cohort, and a long-term cohort sensitivity analysis adding Honold 2025 ($k = 14$; post hoc). The implementation choices for the overlap analysis were made after the primary results were known.

Language restriction No language restrictions were applied to the search.

Country(ies) involved Taiwan.

Other relevant information Safety analysis: overlapping reports were excluded from the safety denominator, which was rebuilt from the full texts of the included reports (22 reports). Reports were classified post hoc by reporting group (independent, developer-affiliated or industry-

sponsored, technique originator without commercial interest), after the distribution of repeat releases had been observed. The review is reported in accordance with PRISMA 2020 and MOOSE.

Other relevant information This protocol was registered on 2 September 2026, after a PubMed scoping search (28 June 2026) and an initial three-database run used for pilot screening (1 September 2026), and before the definitive search (5 September 2026); the review is therefore retrospectively registered. Amendment of 23 September 2026: (1) title updated; scope unchanged. (2) Search record corrected: definitive search 5 September 2026 in PubMed, Embase and CINAHL; Web of Science removed because it was not searched. (3) Hartung–Knapp confidence intervals specified; the Knapp–Hartung F test replaced the subgroup Q test; prediction intervals, Egger's test and GRADE added. (4) Release categories renamed and defined by cutting principle and mechanical nerve protection; no pooled arm moved. (5) Eligibility fields reconciled (randomized trials included; comparative studies contribute their UGCTR arm), and inclusion criteria moved from Information sources to Eligibility. (6) Workflow: AI-drafted screening judgements for 55 records, each confirmed by two reviewers; risk of bias assessed in duplicate for 11 reports and by one reviewer with verification for 14. (7) Sensitivity analyses: Chern overlap resolved at selection; Park-for-Kim substitution implemented ($k = 13$); short-term comparison not completed; largest-registry removal, hemodialysis-cohort exclusion and Honold 2025 ($k = 14$, post hoc) added. (8) Outcomes: procedure duration not reported; QuickDASH and return to work summarized descriptively; safety rules specified (overlap exclusion, rebuilt denominator, event categories, seriousness as reported) and reporting-group classification added post hoc. (9) Author name corrected to Wen-Chih Liu. (10) Yu-Chuan Lin and Po-Chih Shen added as authors, and author affiliations updated.

Keywords Carpal tunnel syndrome; Ultrasonography, interventional; Decompression, surgical; Patient reported outcome measures; Minimal clinically important difference; Systematic review.

Dissemination plans Results will be submitted for publication in a peer-reviewed international journal.

Contributions of each author

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