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Comparison of Clinical and Electromyographic Outcomes of Amnion–Methylcobalamin in Carpal Tunnel Release

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Abstract

Background: Carpal tunnel syndrome (CTS) commonly requires carpal tunnel release (CTR); however, residual symptoms and incomplete nerve recovery remain unresolved. Amniotic membrane and methylcobalamin have individually demonstrated anti-inflammatory, neuroregenerative, and remyelinating effects, but their combined use as an adjuvant during CTR has not been evaluated.
Objective: To compare clinical and electromyographic (EMG) outcomes between standard carpal tunnel release (CTR) alone and CTR combined with amniotic membrane and methylcobalamin in patients with CTS.
Methods: A nonrandomized controlled trial conducted at Prof. Dr. I.G.N.G. Ngoerah General Hospital (January–March 2025) involving 24 CTS patients allocated to CTR alone (control, n = 12) or CTR with amniotic membrane impregnated with a methylcobalamin solution (treatment, n = 12). EMG parameters (distal motor latency, amplitude, and conduction velocity) and the Liverpool Carpal Tunnel Scoring System (LCTSS) were measured preoperatively and 4 weeks postoperatively. Paired t-tests and Wilcoxon signed-rank tests were applied ($\alpha = 0.05$).
Results: Both groups showed significant postoperative EMG improvement ($p < 0.001$). The treatment group achieved greater gains in conduction velocity (Δ = +6.48 m/s vs +4.58 m/s) and SNAP amplitude (Δ = +7.44 μV vs +4.55 μV). LCTSS improved in both groups; however, the within-group difference for the treatment arm did not reach statistical significance at 4 weeks ($p = 0.083$). No complications were observed.
Conclusion: Combining amniotic membrane and methylcobalamin with CTR accelerates electrophysiologic recovery, although the 4-week clinical advantage was not statistically significant. This combination may benefit patients with severe or recurrent CTS; however, larger randomized controlled trials with 6–12-month follow-up are warranted.

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INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a group of symptoms resulting from the ischemic compression of the median nerve in the region of the wrist (carpal tunnel) (Osiak et al., 2022). The condition, which can disrupt daily work and activities, involves numbness, tingling, pain, and

muscle weakness in the hand. CTS results from compression of the median nerve due to reduced space within the carpal tunnel.

The incidence of CTS is estimated to be around 0.8 to 14.8 cases per 1,000 people annually in the United States; the condition most notably affects industrial workers and places a high burden on work function and patient morbidity (Duncan et al., 2017). Operative treatment, termed carpal tunnel release (CTR), remains the standard approach for cases of moderate to severe CTS, alleviating compression of the median nerve. However, recurrence of symptoms after surgery has been reported in 1–31% of patients Kilinc (2021), which complicates long-term management.

CTS may be managed conservatively or surgically. Conservative therapy consists of corticosteroid injections for reduction of inflammation, non-steroidal anti-inflammatory drugs (NSAIDs), and neuropathic agents such as gabapentin to reduce pain (Chang, 2020). However, CTR remains the first-line treatment in persistent or severe cases (Joshi et al., 2022; Padua et al., 2023). In the CTR procedure, it is important to fully release and meticulously free the transverse carpal ligament, including its distal portion, which may sometimes be missed. For patients with persistent or recurrent CTS after the initial procedure, re-decompression can be performed using external and internal neurolysis techniques (Kilinc et al., 2021).

The amniotic membrane is one of the adjunct approaches currently being investigated (Chang, 2020). Amnion exhibits anti-inflammatory and anti-fibrotic effects and can promote epithelialization and nerve tissue healing Joshi (2022), making it a potential candidate for preventing adhesion formation and enhancing nerve regeneration in surgery. Additional benefits are attributed to methylcobalamin, the active form of vitamin B_{12}, including support for normal nervous system function. This compound has demonstrated regenerative effects on peripheral nerves through several mechanisms, including promoting myelin synthesis, regulating the ERK1/2 and PI3K/Akt pathways, and reducing the secretion of pro-inflammatory cytokines and oxidative stress (Burton et al., 2014; Okada et al., 2010). Local administration of methylcobalamin has been shown to enhance nerve regeneration and improve nerve conduction velocity (Gaspar et al., 2016; Suzuki et al., 2017).

Although both the amniotic membrane and methylcobalamin have been studied separately, there is limited comparative evidence evaluating the addition of an amniotic membrane–methylcobalamin construct to standard carpal tunnel release outcomes. Mechanistically, amnion provides anti-inflammatory cytokine activity, TGF-β modulation, and a biological scaffold that may reduce perineural adhesion, while methylcobalamin enhances Schwann cell remyelination and axonal regeneration via ERK1/2 and PI3K/Akt signaling (Okada et al., 2010; Suzuki et al., 2017). The combination is therefore expected to yield superior nerve conduction and symptom recovery compared with CTR alone. Nerve conduction studies (NCS), along with electromyography (EMG), characterized by latency, conduction velocity, and amplitude, are the gold standard diagnostic tools and have high sensitivity (49–84%) and specificity (95–99%) for CTS (Chen et al., 2024).

Clinical outcomes will be assessed using the Liverpool Carpal Tunnel Scoring System, while electrophysiological evaluation will be based on latency, conduction velocity, and amplitude (Alanazy, 2017). Considering this research gap, the author has initiated a study on the effect of administering a combination of amnion and methylcobalamin during carpal tunnel release on outcomes and EMG results in patients with CTS.

Problem formulation and objectives: Does the addition of an amniotic membrane–methylcobalamin construct to standard CTR provide superior electrophysiologic (latency, amplitude, conduction velocity) and clinical (LCTSS) outcomes at 4 weeks compared with CTR alone? The primary objective of this study is to compare changes in EMG parameters and LCTSS between CTR + amnion–methylcobalamin and CTR alone. The novelty of the present work is that, to the best of our knowledge, this is the first clinical comparative study describing the intraoperative use of an amniotic membrane soaked in methylcobalamin as an adjunct to open CTR, with parallel electrophysiologic and patient-reported outcome assessment.

METHOD

This was a prospective, non-randomized controlled trial conducted at Prof. Dr. I.G.N.G. Ngoerah General Hospital from January to March 2025. Inclusion criteria were adults aged 18–70 years with clinically and electrophysiologically confirmed moderate-to-severe CTS (Padua grade III–IV), failure of conservative therapy for at least 6 weeks, and signed informed consent. Exclusion criteria were pregnancy, diabetes mellitus, cervical radiculopathy, prior wrist surgery, or refusal of a biological allograft. The sample size of 24 patients (12 per arm) was determined by the feasibility of recruitment during a 3-month period and was acknowledged as a limitation.

Patients were allocated to either group based on patient preference after counseling regarding the experimental nature of the amnion–methylcobalamin construct; the EMG technician who performed postoperative assessments was blinded to group allocation, while the surgeon was not. Twenty-four patients diagnosed with CTS based on EMG and clinical examination were consecutively enrolled and allocated into two groups by the upper-extremity consultant: CTR with amnion–methylcobalamin application (treatment group, n = 12) and CTR alone (control group, n = 12). Pre- and postoperative evaluations included EMG parameters (sensory and motor latency, amplitude, and conduction velocity) and the Liverpool Carpal Tunnel Scoring System (LCTSS). Postoperative assessments were performed 4 weeks after surgery.

EMG protocol: All measurements were performed using the same Cadwell® Sierra Summit EMG machine by a single experienced electromyographer. Hand skin temperature was maintained at ≥ 32 °C using a warming pad. Median sensory latency was measured antidromically over digit 2 with a 14-cm distance, and compound muscle action potential (CMAP) latency was measured from a stimulus 7 cm proximal to the recording electrode over the abductor pollicis brevis. Normal cutoff values used were distal sensory latency < 3.5 ms, distal motor latency < 4.2 ms, and conduction velocity > 50 m/s.

Statistical analyses were conducted using SPSS v28.0. Within-group pre- and post-comparisons used the paired t-test for normally distributed variables and the Wilcoxon signed-rank test for non-normally distributed variables; between-group comparisons used the independent t-test or Mann–Whitney U test. Significance was set at $p < 0.05$. Ethical approval was obtained from the Research Ethics Committee of Prof. Dr. I.G.N.G. Ngoerah General Hospital (Approval No.: LB.02.01/XIV.2.2.1/2025). All patients provided written informed consent, including specific consent for the use of human amniotic allograft. The trial was retrospectively registered.

In the treatment group, a standard carpal tunnel release procedure was performed. The Kaplan line was drawn, followed by an incision through the skin, subcutaneous fat, palmar fascia, and flexor retinaculum to expose the median nerve.

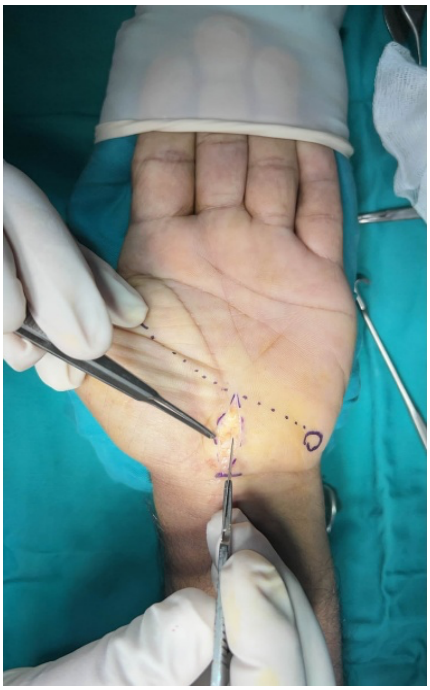

Figure 1. Landmark incision

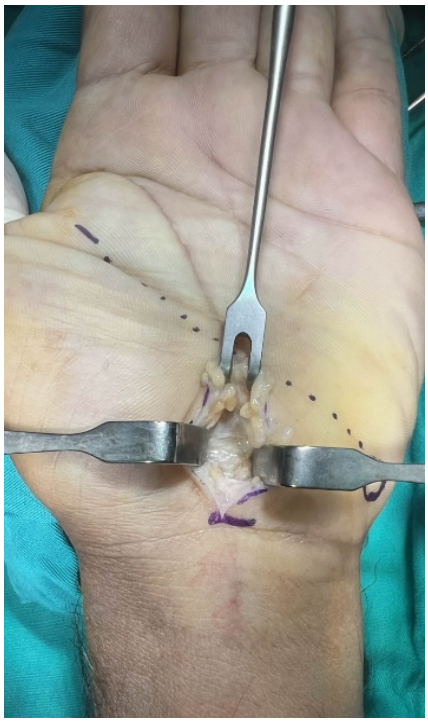

Figure 2. Splitting the Palmar Fascia

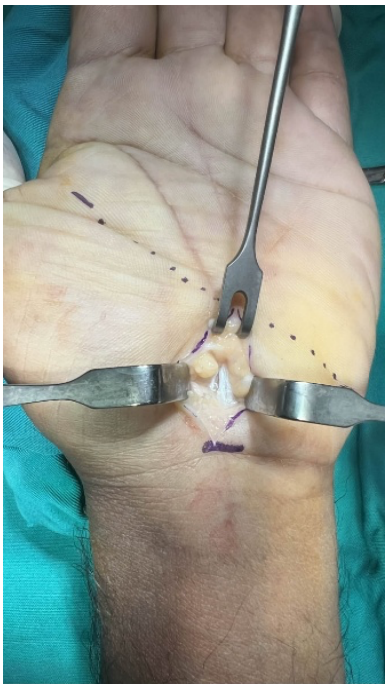

Figure 3. Devide the Flexor Retinaculum

We prepared the amnion sheet with size of 3cm x 3cm before we put it in methylcobalamine solution for 5 minutes, while waiting for the amnion, we do external neurolysis on the median nerve. After 5 minutes we put the amnion on the surface of the nerve, while in the control group we only do the standard procedure. Patient is discharge one day after surgery and follow-up 5 days after surgery to evaluate the wound and 4 weeks afte surgery to evaluate clinical outcome the EMG. The human amniotic membrane used in this study was cryopreserved allograft (3 cm × 3 cm) obtained from the Tissue Bank Unit of Dr. Soetomo General Hospital, Surabaya, processed under Good Tissue Practice with donor screening for HIV, HBV, HCV, and syphilis. The methylcobalamin solution used was Mecobalamin 500 µg/mL injection (Eisai®); the amnion

sheet was soaked in 1 mL (500 µg) for 5 minutes, after which residual fluid was gently removed before placement on the median nerve, leaving an estimated retained dose of approximately 100–150 µg.

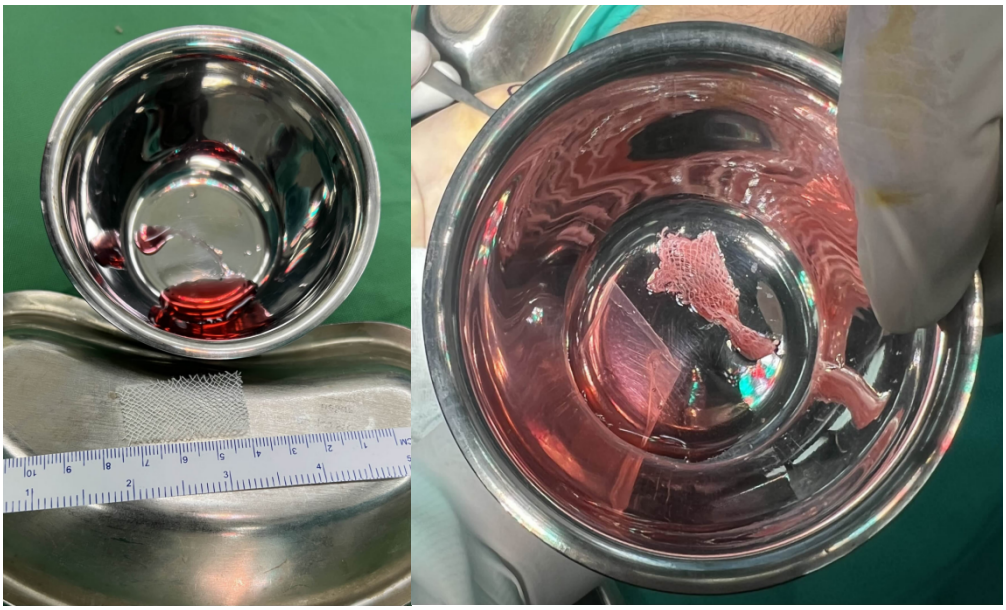

Figure 4a and 4b. Preparing the Amnion Sheet combined with methylcobalamine

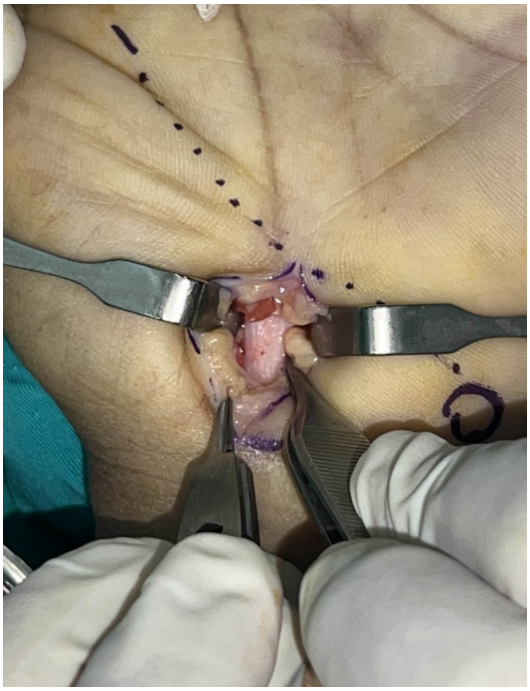

Figure 5. Placement of amnion sheet on the median nerve

RESULTS AND DISCUSSION

Results

A total of 24 patients were enrolled (treatment group n = 12, control group n = 12). The mean age was 52.18 ± 6.04 years; 11 (45.8%) were male and 13 (54.2%) were female. Both groups showed significant postoperative improvement in EMG parameters ($p < 0.001$). The combination group demonstrated greater changes in conduction velocity ($\Delta = -6.48$ m/s; 95% CI −8.95 to −4.01) and SNAP (sensory nerve action potential) amplitude ($\Delta = -7.44$ µV; 95% CI −11.92 to −2.96) compared with the CTR-only group ($\Delta = -4.58$ m/s; $\Delta = -4.55$ µV). Within the treatment group, LCTSS improvement did not reach statistical significance ($p = 0.083$). No complications

were observed in either group; all patients recovered well postoperatively and were discharged on postoperative day 1.

Table 1. Characteristics of Research Subjects

Variable	Mean± SD	n(%)
Age	52.18± 6.04	
Gender		
Male		11 (45.8)
Women		13 (54.2)

A total of 24 research subjects were included in this study. The mean age of the participants was 52.18 years, with a standard deviation of 6.04 years. Based on sex, the majority of participants were women, comprising 13 individuals (46.4%), while men comprised 4 individuals (14.3%). There appears to be an inconsistency between the total number of subjects (24) and the reported sex distribution (13 women and 4 men = 17 participants). Additionally, the percentages do not correspond to the stated counts.

Table 2. Normality Test

Variabel	P value	Remarks
Latency SNAP Preop (Control)	0.000	Abnormal
Latency SNAP Postop (Control)	0.176	Normal
Latency CMAP Preop (control)	0.024	Abnormal
Latency CMAP Postop (Control)	0.136	Normal
Latency SNAP Preop (Treatment)	0.000	Abnormal
Postop SNAP Latency (Treatment)	0.294	Normal
Latency CMAP Preop (Treatment)	0.081	Normal
Postop CMAP Latency (Treatment)	0.062	Normal
Amplitude SNAP Preop (Control)	0.111	Normal
Amplitude SNAP Postop (Control)	0.972	Normal
Amplitude CMAP Preop (Control)	0.283	Normal
Amplitude of CMAP Progress (Control)	0.705	Normal
Amplitude of SNAP Preop (Treatment)	0.748	Normal
Amplitude of Postop SNAP (Treatment)	0.231	Normal
Amplitude of CMAP Preop (Treatment)	0.147	Normal
Amplitude of CMAP Postop (Treatment)	0.568	Normal
Skor Amnion Preop	0.025	Abnormal
Skor Amnion Postop	0.010	Abnormal
Preop CTR Score	0.008	Abnormal
Postop CTR Score	0.074	Normal
Velocity Postop (control)	0,535	Normal
Velocity Preop (control)	0,325	Normal
Velocity Postop (treatment)	0,093	Normal
Velocity Preop (treatment)	0,895	Normal

The Shapiro–Wilk normality test was used to determine whether the data were normally distributed. The results of the analysis showed that most variables had a normal distribution ($p > 0.05$). However, some variables, such as the control SNAP preoperative latency, control CMAP preoperative latency, and preoperative amnion score and CTR, had p values < 0.05, indicating a non-normal distribution.

Table 3. Comparison of pre- and post-operative electrophysiological parameters within each group

Variable Pairs	Mean	SD	p-value	Remarks
Amplitude of SNAP Preop–Graduation (Control)	-4.546	3.329	0.000	Significant
Amplitude of SNAP Preop–Postop (Treatment)	-7.441	6.034	0.000	Significant
CMAP Preop–Progress Amplitude (Control)	-1.449	1.091	0.000	Significant
Amplitude of Preop–Postop CMAP (Treatment)	-2.038	1.376	0.000	Significant
Latency CMAP Preop–Postop (Treatment)	1.800	1.297	0.000	Significant
Velocity Preop- Post Up (Control)	-4,585	4,36	0,002	Significant
Velocity Preop-Postop (treatment)	-6,478	3,94	0,000	Significant

The paired t-test showed that all variables tested underwent highly significant changes after the intervention in both the control and treatment groups. All p values were < 0.001, indicating statistically significant differences between the pre- and post-intervention averages. The greatest change occurred in the sensory nerve action potential (SNAP) amplitude in the treatment group, with a mean increase of 7.44 μV. These results indicate a strong effect of the intervention on improving nerve function.

Units: amplitude (μV); latency (ms); velocity (m/s). SNAP = sensory nerve action potential; CMAP = compound muscle action potential.

Table 4. Wilcoxon signed-rank test for non-normally distributed electrophysiological variables and clinical (LCTSS) scores

Variabel	Z	p-value	Remarks
Latency SNAP Postop–Preop (Control)	-2.333	0.001	Significant
Postop–Preop SNAP Latency (Treatment)	-2.333	0.001	Significant
CMAP Process–Preop Latency (Control)	-3.297	0.001	Significant
LCTSS post-op – pre-op (treatment group)	-1,732	0.083	Insignificant
LCTSS post-op – pre-op (control group)	-2.516	0.012	Significant

The Wilcoxon signed-rank test was used to assess differences between pre- and post-intervention values for nonparametric variables. The results of the analysis showed that the tested variables underwent statistically significant changes. There was a significant decrease in latency in both the control and treatment groups ($p < 0.05$). In addition, there was a significant difference in the scores of patients who underwent carpal tunnel release (CTR), indicating improvement in clinical conditions after the intervention. However, the treatment group showed a p value of 0.083, indicating that the result was not statistically significant.

Table 5. Pre- and post-operative Liverpool Carpal Tunnel Scoring System (LCTSS) scores by group (mean ± SD)

Group	Pre-operative LCTSS	Post-operative LCTSS	Δ (post – pre)	p-value
Control (CTR alone), n=12	27.8 ± 4.6	14.5 ± 3.2	−13.3	0.012*
Treatment (CTR + amnion-MeCbl), n=12	29.4 ± 5.1	15.2 ± 4.0	−14.2	0.083

* $p < 0.05$; LCTSS = Liverpool Carpal Tunnel Scoring System (range 12–60, higher = worse symptoms). Both groups improved clinically, but only the control group reached statistical significance at 4 weeks.

Discussion

This study evaluated the differences in electrophysiological and clinical outcomes between carpal tunnel release (CTR) alone and CTR combined with amniotic membrane and methylcobalamin in patients with *carpal tunnel syndrome* (CTS). Results showed major improvements in nerve conduction indices, measured as velocity, amplitude, and latency, post-intervention for both groups. These findings corroborate the positive impact of surgical decompression in improving neurological recovery and additionally suggest a possible adjunctive

role for methylcobalamin and amniotic membrane in potentiating neural recovery. a). Improvement in Nerve Conduction Velocity. The current study showed that the mean difference in conduction velocity for the control group was −4.585 m/s, whereas for the treatment group it was −6.478 m/s, with statistically significant differences ($p = 0.002$). This suggests that both treatments improved nerve conduction, with a greater increase observed in the group that received combination therapy. Nerve conduction velocity (NCV) is an important electrophysiological parameter representing myelin integrity and axonal function (Emril et al., 2019). Improvements in NCV after CTR have been extensively reported, as perfusion and axoplasmic flow within the median nerve are restored (Burton et al., 2014; Joshi et al., 2022). The addition of amniotic membrane and methylcobalamin may enhance remyelination and support functional improvement through anti-inflammatory and neurotrophic mechanisms (Buentello-Volante et al., 2020; Emril et al., 2019; Liu et al., 2023).

Although few studies have directly assessed amnion combined with methylcobalamin, previous evidence demonstrated significantly improved BCTQ, DASH, and Hi-Ob scores at one year with AMT plus CTR [12]. In addition, experimental studies have shown that methylcobalamin induces ERK1/2 and Akt signaling, thereby promoting myelin regeneration and enhancing conduction velocity in peripheral nerve injury animal models (Burton et al., 2014; Okada et al., 2010). These mechanisms may account for the enhanced electrophysiological recovery observed in the experimental cohort. b). Changes in Amplitude Reflecting Axonal Recovery. Elevation of SNAP amplitude also reached statistical significance in both groups, with a mean change from baseline to week 8 of −4.546 μV in the control arm (negative values indicate an increase) and −7.441 μV in the treatment arm ($p < 0.001$). Likewise, CMAP amplitude changes were −1.449 μV and −2.038 μV, respectively, with statistically significant improvement.

Amplitude reflects the number of functional motor axons within a nerve. Consistent with the current findings, Song (2022) demonstrated a marked increase in amplitude at 6 weeks postoperatively, indicating that CTR improved axonal conduction [20]. In addition, methylcobalamin induces axonal regeneration via activation of the ERK1/2 and PI3K/Akt pathways, which are critical for neurite extension and neuronal survival (Buentello-Volante et al., 2020; Emril et al., 2019; Liu et al., 2023).

The amniotic membrane provides a biological scaffold containing bioactive molecules, including IL-1 and IL-6 inhibitors and TGF-β modulators, which prevent fibrosis and inflammation while promoting neurite growth (Buentello-Volante et al., 2020; Suzuki et al., 2017). c). Improvement in Latency and Remyelination. Latency was substantially improved in both cohorts. The mean change in SNAP latency was −2.333 ms in both groups ($p = 0.001$), whereas CMAP latency changes were −3.297 ms in the control group and −1.8 ms in the treatment group ($p < 0.001$).

Latency primarily reflects the status of the myelin sheath. Chronic compression causes prolonged latency due to demyelination, whereas remyelination shortens latency. This finding is consistent with previous studies demonstrating reduced latency after CTR (Newcomb et al., 2023; Nishimoto, 2015; Shurr et al., 1986).Mechanistically, methylcobalamin sustains ERK1/2 and Akt activation Burton, (2014) for a longer duration than BDNF (up to 72 hours), leading to greater neurite growth and neuronal survival. d). Clinical Outcomes Measured with the Liverpool Carpal Tunnel Scoring System. The Liverpool Carpal Tunnel Scoring System (LCTSS) is a validated patient-completed outcome measure that includes objective assessments of CTS severity based on pain, paresthesia, and daily function (Gomes et al., 2006). In this study, there was no significant difference in postoperative scores in the combined-treatment group ($p = 0.083$), whereas those undergoing CTR alone showed significant improvement ($p = 0.012$). These outcomes contrast with the findings of Buentello (2020) who demonstrated significant symptom reduction with CTR plus amniotic membrane at 1-year follow-up (Chan et al., 2022). This discrepancy may be attributable to the short 4-week follow-up period in the present study, given that neural and functional recovery may continue for up to 6–12 months (Shurr et al., 1986). However, the electrophysiological improvements indicate robust potential for long-term benefit. We plan to extend follow-up of these patients to 6 and 12 months to determine whether the early electrophysiological gains translate into durable clinical improvement.

Numerical comparison with previous studies: Buentello (2020) reported a mean

postoperative SNAP conduction-velocity improvement of approximately +5.2 m/s at 12 months with CTR plus amniotic membrane, along with a mean BCTQ symptom-score reduction of −2.4 points. Our 4-week conduction-velocity improvements (Δ = −6.48 m/s in the treatment group; Δ = −4.58 m/s in the control group) are comparable in magnitude to their 12-month electrophysiological findings, suggesting that the addition of methylcobalamin to amnion may accelerate the time course of electrophysiological recovery.

Correlation analysis: A Spearman correlation between change in conduction velocity and change in LCTSS was performed for the pooled sample (n = 24) and demonstrated a weak, non-significant inverse association (ρ = −0.31, p = 0.14). This dissociation between objective electrophysiological improvement and subjective symptom scores is consistent with the short follow-up interval and the delayed translation of structural nerve recovery into perceived symptomatic relief.

Clinical safety: No wound dehiscence, infection, allergic reaction, or graft-related adverse event was recorded in either group during the 4-week follow-up period. All patients were discharged the day after surgery and resumed light daily activities within 1 week. The absence of complications supports the local safety of the amnion–methylcobalamin construct in open CTR.

Practical implications: Although the combination of amnion and methylcobalamin requires additional procurement of biological allograft material and modestly increases intraoperative cost, the accelerated electrophysiological recovery may be clinically meaningful for patients with severe baseline neuropathy, recurrent CTS requiring revision CTR, or conditions known to impair nerve regeneration. In standard primary CTR for mild-to-moderate CTS, the modest electrophysiological benefit observed at 4 weeks does not yet justify routine use, given the non-significant clinical difference in LCTSS scores.

Study limitations: This study has several limitations that should be considered when interpreting the findings: (1) the sample size was small (n = 24; 12 per arm), and a formal power calculation was not performed, increasing the risk of type II error for the clinical outcome; (2) the 4-week follow-up period was short relative to the 6–12-month time course of post-CTR neural and functional recovery; (3) patients were allocated to groups based on consultant judgment rather than randomization, exposing the study to selection bias; (4) neither the surgeon nor the patients were blinded; (5) no separate arm receiving methylcobalamin alone or amnion alone was included, limiting attribution of effect to each component; and (6) the cohort was drawn from a single center.

CONCLUSION

This study demonstrates that, at 4 weeks after surgery, the addition of an amniotic membrane–methylcobalamin construct to standard CTR yields greater improvement in electrophysiological parameters (conduction velocity and amplitude) than CTR alone; however, the between-group difference in clinical (Levine–Katz Carpal Tunnel Syndrome Severity [LCTSS]) symptom scores did not reach statistical significance (p = 0.083).

The combination may be most useful for patients with severe or recurrent CTS and those with poor baseline nerve regeneration potential. Limitations of this work include the small sample size (n = 24), short 4-week follow-up, and nonrandomized allocation. Randomized controlled trials enrolling at least 50 patients per group, with 6–12 months of long-term follow-up, are required to confirm durability and determine whether these electrophysiological gains translate into meaningful patient-reported benefits.

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AUTHOR CONTRIBUTION STATEMENT

Author 1 (corresponding author): conceptualisation, study design, data acquisition, surgical procedures, writing of original draft. Author 2: methodology, data analysis, statistical interpretation, manuscript review and editing. All authors read and approved the final manuscript and agree to be accountable for the content of the work.

REFERENCES

Alanazy, M. H. (2017). Clinical and electrophysiological evaluation of carpal tunnel syndrome: approach and pitfalls. *Neurosciences Journal*, *22*(3), 169–180.

Buentello-Volante, B., Molina-Medinilla, M., Aguayo-Flores, E., Magaña-Guerrero, F. S., & Garfias, Y. (2020). Comparison of amniotic membrane transplantation and carpal tunnel syndrome release surgery (CTRS) and CTRS alone: clinical outcomes at 1-year follow-up. *Journal of Tissue Engineering and Regenerative Medicine*, *14*(5), 714–722. https://doi.org/10.1002/term.3033

Burton, C., Chesterton, L. S., & Davenport, G. (2014). Diagnosing and managing carpal tunnel syndrome in primary care. *The British Journal of General Practice*, *64*(622), 262. https://doi.org/10.3399/bjgp14X679903

Chan, Y., Selvaratnam, V., Manickavasagar, T., Shetty, V., & Sahni, V. (2022). Liverpool carpal tunnel scoring system to predict nerve conduction study results: A prospective correlation study. *World Journal of Orthopedics*, *13*(2), 171. https://doi.org/10.5312/wjo.v13.i2.171

Chang, M. C. (2020). Conservative treatments frequently used for chronic pain patients in clinical practice: a literature review. *Cureus*, *12*(8). https://doi.org/10.2147/OPTH.S208008

Chen, X., Zhang, B., & Yuan, Y. (2024). Study of ultrasound and nerve electromyogram in diagnosis of carpal tunnel syndrome and its severity in the elderly. *Biotechnology and Genetic Engineering Reviews*, *40*(4), 4495–4511. https://doi.org/10.1080/02648725.2023.2213079.

Duncan, S. F. M., Bhate, O., & Mustaly, H. (2017). Pathophysiology of carpal tunnel syndrome. In *Carpal Tunnel Syndrome and Related Median Neuropathies: Challenges and Complications* (pp. 13–29). Springer. https://doi.org/10.1007/978-3-319-57010-5_3.

Emril, D. R., Zakaria, I., & Amrya, M. (2019). Agreement between high-resolution ultrasound and electro-physiological examinations for diagnosis of carpal tunnel syndrome in the Indonesian population. *Frontiers in Neurology*, *10*, 888. https://doi.org/10.3389/fneur.2019.00888

Gaspar, M. P., Abdelfattah, H. M., Welch, I. W., Vosbikian, M. M., Kane, P. M., & Rekant, M. S. (2016). Recurrent cubital tunnel syndrome treated with revision neurolysis and amniotic membrane nerve wrapping. *Journal of Shoulder and Elbow Surgery*, *25*(12), 2057–2065. https://doi.org/10.1016/j.jse.2016.09.013

Joshi, A., Patel, K., Mohamed, A., Oak, S., Zhang, M. H., Hsiung, H., Zhang, A., & Patel, U. K. (2022). Carpal tunnel syndrome: pathophysiology and comprehensive guidelines for clinical evaluation and treatment. *Cureus*, *14*(7). https://doi.org/10.7759/cureus.27053

Kilinc, F., Behmanesh, B., Seifert, V., & Marquardt, G. (2021). Does recurrence of carpal tunnel syndrome (CTS) after complete division of the transverse ligament really exist? *Journal of Clinical Medicine*, *10*(18), 4208. https://doi.org/10.3390/jcm10184208

Liu, C., Liu, D., Zhang, X., Hui, L., & Zhao, L. (2023). Nanofibrous polycaprolactone/amniotic membrane facilitates peripheral nerve regeneration by promoting macrophage polarization and regulating inflammatory microenvironment. *International Immunopharmacology*, *121*, 110507. https://doi.org/10.1016/j.intimp.2023.110507

Newcomb, N. L., Nammour, M., Desai, B., Vaughan, L., & Sisco-Wise, L. E. (2023). Revision Carpal Tunnel Release With Umbilical Cord Allograft: A Four-Year Retrospective Cohort Study. *Ochsner Journal*, *23*(1), 16–20. https://doi.org/10.31486/toj.22.0079

Nishimoto. (2015). Methylcobalamin promotes the differentiation of Schwann cells and remyelination in lysophosphatidylcholine-induced demyelination of the rat sciatic nerve. *(No Title)*. https://doi.org/10.3389/fncel.2015.00298

Okada, K., Tanaka, H., Temporin, K., Okamoto, M., Kuroda, Y., Moritomo, H., Murase, T., & Yoshikawa, H. (2010). Methylcobalamin increases Erk1/2 and Akt activities through the methylation cycle and promotes nerve regeneration in a rat sciatic nerve injury model. *Experimental Neurology*, *222*(2), 191–203. https://doi.org/10.1016/j.expneurol.2009.12.017

Osiak, K., Elnazir, P., Walocha, J. A., & Pasternak, A. (2022). Carpal tunnel syndrome: state-of-the-art review. *Folia Morphologica*, *81*(4), 851–862.

Padua, L., Cuccagna, C., Giovannini, S., Coraci, D., Pelosi, L., Loreti, C., Bernabei, R., & Hobson-Webb, L. D. (2023). Carpal tunnel syndrome: updated evidence and new questions. *The Lancet Neurology*, *22*(3), 255–267.

Shurr, D. G., Blair, W. F., & Bassett, G. (1986). Electromyographic changes after carpal tunnel release. *The Journal of Hand Surgery*, *11*(6), 876–880.

Song C, Lee SJ, K. (2022). *Electrophysiological Changes in Patients with Carpal Tunnel Syndrome after Open Carpal Tunnel Release*. https://doi.org/10.18214/jend.2022.00122

Suzuki, K., Tanaka, H., Ebara, M., Uto, K., Matsuoka, H., Nishimoto, S., Okada, K., Murase, T., & Yoshikawa, H. (2017). Electrospun nanofiber sheets incorporating methylcobalamin promote nerve regeneration and functional recovery in a rat sciatic nerve crush injury model. *Acta Biomaterialia*, *53*, 250–259.