

CASE REPORT

Bilateral ultrasound-guided axillary brachial plexus block for hand reconstruction in severe post-burn cervicofacial contracture: A Case Report

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ABSTRACT

Background. Severe post-burn cervicofacial contractures can complicate airway management during reconstructive surgery.

Objective. To describe bilateral axillary brachial plexus blockade, serial physiological measurements, and recovery during bilateral hand contracture release.

Methods. A 47-year-old woman weighing 56 kg with cervicofacial flap scarring underwent bilateral ultrasound-guided axillary blocks without sedation. The reported dose was 20 mL of 2% lidocaine (400 mg) per side, with a reported 30-minute interval. Hemodynamics, sensorimotor onset, adverse events, and recovery were assessed at twelve perioperative time points.

Results. Sensory and motor blockade were reported at 12 and 15 minutes per limb, respectively. Surgery lasted 95 minutes without airway instrumentation. Recorded mean arterial pressure ranged from 85.33 to 96.00 mmHg (−7.25% to +4.35% from baseline), rate-pressure product from 8,584 to 10,752 bpm·mmHg, and room-air oxygen saturation from 99% to 100%. No clinical signs of local anesthetic systemic toxicity were reported. The reported Naranjo score was 0. No systemic opioids were required, discharge occurred on postoperative day two, and six-week follow-up found no persistent neurological deficits.

Conclusion. Bilateral axillary blockade permitted hand reconstruction without airway instrumentation in this patient. The single-case design cannot establish comparative superiority or general pharmacokinetic safety; the reported cumulative lidocaine dose requires author clarification.

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1. Introduction

Thermal trauma represents one of the most devastating physical injuries encountered in modern clinical medicine, frequently culminating in profound anatomical disfigurement, debilitating functional impairment, and permanent soft tissue contractures.¹ When deep burns involve the delicate cervicothoracic region, the healing process is characterized by aberrant dermal-fascial scar contracture, severe loss of tissue elasticity, and restricted mobility.² Following primary acute survival, surgical reconstruction using locoregional fasciocutaneous rotation flaps or skin grafting restores baseline cutaneous coverage but inevitably establishes a rigid, disorganized fibrotic envelope around the neck and lower face.³

In the domain of clinical anesthesiology, post-burn cervicofacial contractures represent a quintessential and universally feared difficult airway scenario.⁴ The pathological tethering of the chin to the anterior thoracic wall fundamentally disrupts the three primary anatomical axes—oral, pharyngeal, and laryngeal—whose dynamic alignment in the classical sniffing position is an absolute prerequisite for direct line-of-sight visual laryngoscopy.⁵ Fixed cervical flexion prevents the mandatory atlanto-

occipital extension, while hypertrophic perioral scarring and microstomia severely restrict inter-incisor opening, rendering standard laryngoscope blades and videolaryngoscope spatulas physically impossible or exceedingly traumatic to introduce.⁶

In addition, the difficulty in post-burn airway management is rarely restricted to endotracheal intubation alone; bag-mask ventilation is equally and perilously compromised.⁷ Cicatricial facial distortion, altered mandibular contours, severe microstomia, and lower lip eversion frequently preclude the establishment of an airtight seal with standard anesthetic facemasks.⁸ When general anesthesia with neuromuscular blockade is induced in this setting, the abrupt abolition of upper airway tone precipitates rapid pharyngeal collapse, instantaneously converting a difficult intubation scenario into a catastrophic 'cannot intubate, cannot oxygenate' crisis.⁹

While awake fiberoptic intubation has historically served as the gold standard for anticipated difficult airways in burn reconstructive surgery, its execution in patients with extensive cervicofacial flap reconstruction is technically challenging.¹⁰ Distorted endonasal architecture, cicatricial synechiae, and hypervascular friable mucosal tissues increase the risk of mucosal laceration and hemorrhage

upon scope passage.¹¹ Even minor bleeding within the narrow, scarred airway can instantly obscure the fiberoptic lens, transforming a controlled awake procedure into an unmanageable crisis.¹² In addition, topical local anesthetic application to the airway mucosa carries the risk of airway hyperreactivity, coughing, laryngospasm, and potential systemic toxicity.^{10,12}

Faced with these formidable challenges, a paradigm shift in perioperative planning has emerged: rather than focusing exclusively on mastering a hostile airway, anesthesiologists may achieve far greater clinical safety by rendering the airway functionally irrelevant to the surgical procedure.¹³ In reconstructive surgery of the distal upper extremity, such as the release of post-burn flexion contractures of the hands and digits, regional anesthesia provides an elegant, non-invasive definitive strategy.¹⁴ By establishing complete surgical anesthesia across the operative field while preserving unassisted spontaneous ventilation, regional blockade completely removes the airway from the perioperative risk equation.¹⁵ This approach completely eliminates the hazards of general anesthetic induction, neuromuscular paralysis, tracheal instrumentation, barotrauma, ventilator-associated lung injury, and postoperative extubation failure.^{13,15}

Among the anatomical approaches to the brachial plexus, the axillary brachial plexus block presents unique and decisive advantages for the patient with extensive cervicofacial flap reconstruction.¹⁶ More proximal techniques, including the interscalene and supraclavicular approaches, are anatomically proximal to the burn field, where fibrotic tissue extension, altered sonographic landmarks, and altered fascial planes may compromise needle visualization and local anesthetic spread.¹⁷ More critically, proximal approaches carry an inherent and substantial incidence of phrenic nerve blockade and resultant diaphragmatic hemiparesis, which can precipitate acute respiratory compromise in patients with baseline thoracic restriction from chest wall scarring.¹⁸ Supraclavicular blocks additionally carry a small but finite risk of pneumothorax, a catastrophic complication in a patient whose airway cannot be readily instrumented.^{16,18} In sharp contrast, the axillary approach targets the terminal branches of the brachial plexus—the median, ulnar, radial, and musculocutaneous nerves—within the axillary neurovascular sheath in the proximal arm, an anatomical territory completely distant and shielded from the cervical scar envelope.¹⁶

The integration of high-resolution ultrasonography has fundamentally transformed the efficacy, precision, and safety of axillary brachial plexus blockade over the past two decades.¹⁹ Real-time ultrasound guidance permits direct cross-sectional visualization of the pulsating axillary artery, the surrounding adjacent veins, and the four individual neural targets within their distinct fascial compartments.²⁰ Under direct in-plane needle navigation, the anesthesiologist can verify extra-neural needle tip positioning, avoid inadvertent vascular puncture, and monitor the circumferential, hydro-dissecting perineural spread of local anesthetic—the hallmark 'doughnut sign'—around each nerve trunk.²¹ This visual precision drastically reduces the minimum volume of local anesthetic required for complete sensorimotor blockade and virtually eliminates the risk of inadvertent intravascular injection and local anesthetic systemic toxicity.^{19,21}

Despite the recognized theoretical benefits of peripheral nerve blockade in burn care, comprehensive empirical

literature detailing the use of exclusively ultrasound-guided bilateral axillary brachial plexus block as the definitive, sole anesthetic strategy in an adult patient with severe post-burn cervicofacial flap reconstruction and an anticipated difficult airway remains remarkably sparse in international literature.²² The core scientific novelty of this observational analytic investigation lies in demonstrating the absolute feasibility, pharmacokinetic safety, and longitudinal physiological stability of a complete 'airway circumvention paradigm'—formulating the foundational clinical thesis that physical distance from a hostile airway represents a deliberate, superior, and reproducible anesthetic architecture.²³ The explicit objective of this study is to characterize the longitudinal hemodynamic trajectories, sensorimotor block latency, causality evaluation, and perioperative outcomes of bilateral ultrasound-guided axillary brachial plexus blockade in a patient with severe post-burn cervicofacial contracture undergoing bilateral hand contracture release, thereby deriving evidence-based guidelines for perioperative airway risk mitigation.²⁴

2. Methods

2.1. Study Design & Epidemiological Framework

This investigation was designed as a prospective observational analytic case study adhering strictly to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines and the CARE consensus criteria for clinical observational reports.²⁵ The study design was selected to permit continuous longitudinal tracking of physiological, pharmacokinetic, and sensorimotor trajectories in a uniquely complex clinical scenario where randomized interventional trials are methodologically and ethically impermissible.^{22,25} The observational framework was conducted within the Department of Anesthesiology and Intensive Therapy at Dr. Moewardi General Hospital in Surakarta, Central Java, Indonesia, a tertiary academic referral center specializing in advanced reconstructive burn surgery, complex regional anesthesia, and difficult airway management.

2.2. Ethical Governance & Participant Consent

Ethical governance was established in full accordance with the international ethical standards outlined in the Declaration of Helsinki of the World Medical Association.²⁶ Formal prospective institutional ethical clearance and protocol approval were granted by the CMHC Research Center Ethics Committee, Indonesia, under official protocol approval number 2026/7184. Prior to procedural initiation, the patient was provided with verbal and written explanations regarding the anticipated difficult airway, the proposed regional anesthetic strategy, the rationale for complete avoidance of general anesthesia, potential risks including local anesthetic systemic toxicity and nerve injury, and the predefined rescue protocols should the regional block prove incomplete. The patient provided written informed consent for the execution of the anesthetic procedure, longitudinal physiological data capture, and publication of all clinical data, laboratory findings, radiological imaging, and clinical photographs. In accordance with international medical publication ethics, the International Committee of Medical Journal Editors guidelines, and the Committee on Publication Ethics regulations, all facial photographs were permanently anonymized by affixing solid black obscuration bars across

the ocular region to protect patient confidentiality without obscuring pathological cervicofacial landmarks.

2.3. Participant Eligibility & Diagnostic Ascertainment

Participant eligibility was determined through an multidisciplinary preoperative evaluation conducted collaboratively by the attending anesthesiology consultant, the plastic reconstructive surgery team, and dedicated clinical research staff.²⁷ The index participant was a 47-year-old female presenting for elective bilateral hand contracture release and split-thickness skin grafting, with extensive post-burn deformities resulting from a catastrophic flame burn sustained fifteen years previously. Inclusion criteria comprised: adult patient undergoing elective reconstructive surgery of the upper extremities; presence of severe post-burn cervicofacial cicatricial deformities and prior flap reconstruction; formal clinical and anatomical documentation of an anticipated difficult airway; absence of contraindications to peripheral nerve blockade (including uncorrectable coagulopathy, severe local infection at the axillary puncture sites, or known local anesthetic allergy); and willingness to participate in awake regional anesthesia. A thorough preoperative airway examination was performed, evaluating inter-incisor distance, modified Mallampati classification, thyromental distance, range of cervical motion, submandibular tissue compliance, and anticipated bag-mask seal integrity.

2.4. Longitudinal Observation Protocol & Analytical Measurements

The observational protocol encompassed twelve distinct, standardized perioperative observation intervals spanning from initial baseline operating room admission through intraoperative milestones, post-anesthesia care unit recovery, hospital discharge, and six-week outpatient follow-up.²⁸ Standardized physiological monitoring was established immediately upon arrival in the operating suite using an multiparameter patient monitor. Monitored physiological variables included: continuous five-lead electrocardiography for heart rate and cardiac rhythm analysis; automated non-invasive arterial blood pressure measured at five-minute intervals; continuous pulse oximetry for peripheral capillary oxygen saturation; and continuous microstream capnography via a dedicated nasal cannula for end-tidal carbon dioxide monitoring and spontaneous respiratory rate verification. Baseline hemodynamics were recorded at time zero (T_0) following ten minutes of undisturbed supine acclimatization.

2.5. Calculated Cardiovascular Variables & Kinetic Equations

Analytical calculations of derived cardiovascular variables were performed systematically across all observation points.²⁹ Mean arterial pressure was calculated using the standardized physiological formula: $MAP = DBP + 1/3(SBP - DBP)$, where SBP represents systolic blood pressure and DBP represents diastolic blood pressure in mmHg. Rate-pressure product, an established surrogate index of myocardial oxygen consumption and hemodynamic stress, was calculated using the formula: $RPP = HR \times SBP$, where HR represents heart rate in beats per minute and SBP represents systolic blood pressure in mmHg. Percentage delta change relative to pre-procedural baseline was computed for mean arterial pressure and heart rate using the serial trajectory equation: $\Delta\% = [(T_n - T_0) / T_0] \times 100\%$, where T_n denotes the parameter value at

observation interval n and T_0 represents the baseline value.

2.6. Sensorimotor Blockade & Pain Trajectory Scoring

Sensorimotor blockade kinetics were quantified prospectively at five-minute intervals following local anesthetic injection until complete surgical anesthesia was achieved.³⁰ Sensory blockade was evaluated across the distinct cutaneous dermatomal distributions of the four target nerves—median nerve (palmar aspect of the index finger), ulnar nerve (hypothenar eminence and fifth digit), radial nerve (first dorsal web space), and musculocutaneous nerve (lateral forearm)—using a three-point pinprick grading scale: 0 = sharp sensation (normal), 1 = dull sensation (analgesia), and 2 = no sensation (complete anesthesia).³⁰ Motor blockade was assessed using a modified four-point upper extremity Bromage score: 0 = normal motor power across all muscle groups, 1 = reduced motor power with ability to flex and extend fingers, 2 = inability to flex fingers with preserved wrist movement, and 3 = complete motor paralysis of the forearm, wrist, and hand.³¹ Complete block success was defined as sensory grade 2 and motor Bromage score 3 across all four nerve distributions bilaterally.

2.7. Safety Surveillance & Adverse Reaction Monitoring

Longitudinal postoperative pain intensity was measured using the validated eleven-point Numerical Rating Scale, ranging from 0 (no pain) to 10 (worst imaginable pain), assessed hourly during the initial six hours in the post-anesthesia care unit, upon transfer to the surgical ward, and daily until hospital discharge.³² Cumulative perioperative systemic opioid consumption was tracked in oral morphine milligram equivalents. Surveillance for local anesthetic systemic toxicity was conducted continuously using a structured clinical symptom checklist (perioral numbness, metallic taste, tinnitus, lightheadedness, visual disturbances, tremors, cardiac dysrhythmias, or hemodynamic instability) and evaluated using the Naranjo Adverse Drug Reaction Probability Scale.³³

2.8. Comparative & Analytical Framework

To assess the clinical superiority and safety divergence of the anatomical circumvention paradigm against historical cohorts, a comparative analytical framework was synthesized.³⁴ This framework integrated a systematic global literature benchmark of previously reported airway strategies in post-burn cervicofacial contracture cohorts, contrasting procedural success rates, incidence of airway-related critical incidents, duration of postoperative mechanical ventilation, systemic opioid requirements, and intensive care length of stay. The comparative framework used the Bradford Hill criteria for causality to establish whether the deliberate avoidance of airway manipulation was biologically and methodologically causal in achieving zero airway-related morbidity.^{34,35}

2.9. Biostatistical Analysis & Time-Series Trajectory Modeling

In accordance with the biostatistical principles governing single-subject observational studies ($n = 1$), inferential statistical testing—such as Student t-tests, analysis of variance, or chi-square distributions—was strictly avoided to prevent the generation of spurious, methodologically invalid p-values.³⁶ The biostatistical analysis focused entirely on high-resolution descriptive analytics, time-series trajectory modeling, and serial percentage delta

variation calculations. Tabular data were organized into formal three-horizontal-line formatting. Objective causality assessment was conducted using the Bradford Hill framework, the Naranjo Adverse Drug Reaction Probability Scale, and the World Health Organization–Uppsala Monitoring Centre causality classification system. Data verification and mathematical cross-consistency audits were independently executed across all clinical parameters to guarantee absolute concordance between narrative text, tabular data, and graphic visualizations.

3. Results

3.1. Baseline Clinical Profiling & Airway Risk Stratification

The patient, a 47-year-old female weighing 56 kg with a height of 158 cm (body mass index 22.4 kg/m²), presented

with severe functional disability of both hands secondary to chronic post-burn flexion contractures, as detailed in Table 1. Fifteen years prior to the index admission, she had sustained an extensive full-thickness flame burn involving the anterior cervical zone, lower face, anterior chest wall, and bilateral upper extremities. Following the initial injury, she underwent multiple reconstructive interventions, most notably a large rotational fasciocutaneous flap transposition to reconstruct the anterior neck, along with multiple split-thickness skin grafts. Over the subsequent decade and a half, chronic fibrotic remodeling and myofibroblastic traction generated dense hypertrophic scar bands connecting the reconstructed neck flap to the sternum and clavicles, as well as severe cicatricial contractures across both upper extremities.

Table 1. Baseline demographic, anthropometric, and airway anatomical risk stratification.

Clinical & Anatomical Parameter	Baseline Measurement / Finding	Reference / Normal Range	Risk Stratification & Clinical Impact
Chronological age	47 years	N/A	Adult reconstructive population
Biological sex	Female	N/A	Standard sex-stratified pharmacokinetics
Body weight	56 kg	N/A	Critical for local anesthetic dose capping (7.1 mg/kg/side)
Body height	158 cm	N/A	Anthropometric proportionality
Body mass index (BMI)	22.4 kg/m ²	18.5–24.9 kg/m ²	Eutrophic / normoweight habitus
ASA physical status	Class II	Class I–VI	Systemic cicatricial deformity, nil active systemic disease
Primary burn etiology	Severe flame burn (15 years prior)	N/A	Full-thickness cervical, facial, thoracic, and bilateral upper limb involvement
Reconstructive history	Cervical fasciocutaneous rotational flap	N/A	Extensive dense fibrotic scar envelope with submandibular tethering
Planned surgical procedure	Bilateral hand contracture release + STSG	N/A	Distal upper extremity territory, bilateral operative fields
Modified Mallampati classification	Class III	Class I–IV	Predictor of difficult laryngoscopy; soft palate and uvula base barely visible
Inter-incisor distance (IID)	≈ 2.5 cm	≥ 4.0 cm	Severe microstomia; restricts insertion of standard videolaryngoscope blades
Thyromental distance (TMD)	≈ 5.0 cm	≥ 6.5 cm	Short anterior mandibular space; prevents tongue displacement
Cervical extension angle	< 30° from neutral position	≥ 80° from neutral	Severe fixed flexion deformity; loss of 'sniffing position' alignment
Submandibular compliance	Markedly reduced / rigid induration	Soft, compressible tissue	Tongue cannot be displaced into submental space during laryngoscopy
Predicted Cormack–Lehane grade	Grade III–IV	Grade I–IV	Anticipated failure of direct visual glottic exposure
Anticipated bag-mask ventilation	Difficult / impossible seal	Easy bilateral ventilation	Facial contour scarring, lip eversion, and microstomia compromise seal
Baseline pulmonary function	RR 18 breaths/min, SpO ₂ 99% on room air	RR 12–20, SpO ₂ ≥ 95%	Adequate resting gas exchange without respiratory distress
Definitive anesthetic strategy	Bilateral US-guided axillary plexus block	N/A	Complete anatomical circumvention of hostile cervicofacial airway

Note: ASA, American Society of Anesthesiologists; BMI, body mass index; IID, inter-incisor distance; N/A, not applicable; RR, respiratory rate; SpO₂, peripheral capillary oxygen saturation; STSG, split-thickness skin graft; TMD, thyromental distance; US, ultrasound.

3.2. Airway Examination Findings & Functional Impairment

Clinical and plain radiographic examination of the upper extremities revealed fixed flexion contractures of the metacarpophalangeal and interphalangeal joints with palmar webbing, as illustrated in Figure 1 (Panel A showing severe flexion deformity and Panel B demonstrating bony alignment without intrinsic osseous

destruction). Cervicofacial appearance and severe airway distortion are demonstrated in Figure 2, where rotational flap contours and perioral cicatricial tethering are clearly visible in the anterior view (Panel A, with patient eyes anonymized with a solid black bar in compliance with ICMJE ethical standards) and marked fixed cervical flexion (< 30° from neutral) with complete obliteration of the submandibular compliance space is demonstrated in the lateral profile (Panel B). Perioral examination revealed

severe microstomia with an inter-incisor distance of approximately 2.5 cm, thyromental distance of 5.0 cm, and modified Mallampati class III view, predicting a Cormack–

Lehane grade III or IV glottic view and impossible bag-mask seal. Resting respiratory status was stable (RR 18 breaths/min, SpO₂ 99% on room air).



Figure 1. (A) Clinical appearance of the right hand demonstrating fixed flexion contractures of the metacarpophalangeal and interphalangeal joints; (B) plain radiograph of the right hand showing the fixed-flexion bony posture without primary osseous deformity.

(A) Anterior View: Flap Scarring & Microstomia [Eyes Anonymized per ICMJE Guidelines]



(B) Lateral View: Severe Cervical Flexion [Eye Anonymized per ICMJE Guidelines]



Figure 2. Cervicofacial appearance after burn injury and rotational flap reconstruction with solid black anonymization bars over ocular regions in accordance with ICMJE/COPE guidelines. (A) Anterior view demonstrating rotational flap scar contour, perioral cicatricial tethering, and microstomia; (B) lateral view showing fixed cervical flexion and complete obliteration of the submandibular compliance space.

3.3. Preoperative Diagnostic, Coagulation, & Organ Function Clearance

Routine laboratory investigations, hemostatic assays, and cardiopulmonary diagnostic testing confirmed unhindered organ clearance and normal coagulation pathways, as summarized in Table 2.³⁷ Hematological profiling demonstrated a hemoglobin concentration of 12.6 g/dL, hematocrit of 38.0%, total leukocyte count of 7.4×10^9 /L, and platelet count of 268×10^9 /L. Coagulation parameters showed prothrombin time 11.8 seconds (international

normalized ratio 1.04) and activated partial thromboplastin time 30.4 seconds. Serum electrolytes and renal panels revealed sodium 138 mmol/L, potassium 4.1 mmol/L, blood urea nitrogen 22.0 mg/dL, and serum creatinine 0.7 mg/dL. Hepatic enzymes were within normal ranges (aspartate aminotransferase 24.0 U/L, alanine aminotransferase 22.0 U/L). Normal cardiopulmonary architecture was depicted in Figure 3, with posteroanterior chest radiography demonstrating clear lung fields bilaterally, normal cardiothoracic ratio, and absence of fibrothorax or pleural distortion.

Table 2. Preoperative hematological, coagulation, biochemical, and cardiopulmonary baseline parameters.

Diagnostic Investigation	Quantitative Result	Standard Reference Range	Clinical Interpretation & Anesthetic Clearance
Hemoglobin concentration	12.6 g/dL	12.0–16.0 g/dL	Normal; adequate oxygen-carrying capacity
Hematocrit ratio	38.0%	36.0–48.0%	Normal; optimal blood viscosity

Diagnostic Investigation	Quantitative Result	Standard Reference Range	Clinical Interpretation & Anesthetic Clearance
Total leukocyte count	$7.4 \times 10^9/L$	$4.0\text{--}11.0 \times 10^9/L$	Normal; absence of systemic leukocytosis or active infection
Platelet count	$268 \times 10^9/L$	$150\text{--}450 \times 10^9/L$	Normal; adequate primary hemostasis for needle puncture
Prothrombin time (PT)	11.8 seconds	11.0–13.5 seconds	Normal extrinsic coagulation pathway integrity
International normalized ratio (INR)	1.04	0.85–1.15	Normal; zero coagulopathic bleeding risk
Activated partial thromboplastin time	30.4 seconds	25.0–35.0 seconds	Normal intrinsic coagulation pathway integrity
Serum sodium (Na^+)	138 mmol/L	135–145 mmol/L	Normal extracellular electrolyte homeostasis
Serum potassium (K^+)	4.1 mmol/L	3.5–5.0 mmol/L	Normal; absence of hyperkalemia/cardiac conduction risk
Blood urea nitrogen (BUN)	22.0 mg/dL	10.0–50.0 mg/dL	Normal renal nitrogenous metabolic clearance
Serum creatinine	0.7 mg/dL	0.6–1.1 mg/dL	Normal glomerular filtration; unhindered drug clearance
Random blood glucose	95.0 mg/dL	70.0–140.0 mg/dL	Normoglycemia; no diabetic microvascular risk
Aspartate aminotransferase (AST)	24.0 U/L	< 40.0 U/L	Normal hepatocellular integrity; unimpaired lidocaine clearance
Alanine aminotransferase (ALT)	22.0 U/L	< 40.0 U/L	Normal hepatic functional reserve
12-lead electrocardiogram (ECG)	Normal sinus rhythm, 76 bpm	Sinus rhythm, 60–100 bpm	Normal PR and QTc intervals; zero ischemic changes
Posteroanterior chest radiograph	Clear lung fields, normal CTR	Normal bronchovascular pattern	Absence of fibrothorax, atelectasis, or tracheal deviation

Note: ALT, alanine aminotransferase; AST, aspartate aminotransferase; CTR, cardiothoracic ratio; INR, international normalized ratio; PT, prothrombin time; QTc, corrected QT interval.

Posteroanterior Chest Radiograph (Clear Lung Fields, Normal CTR)



Figure 3. Posteroanterior chest radiograph on admission showing clear lung fields bilaterally, normal cardiothoracic ratio, and absence of fibrothorax or pleural scarring.

3.4. Procedural Execution of Ultrasound-Guided Bilateral Axillary Blockade

The anesthetic procedure commenced in the operating room under sterile conditions. A high-frequency linear ultrasound transducer (10–15 MHz) was placed transversely across the proximal right axilla. High-

resolution cross-sectional sonography visualized the pulsating, round, anechoic axillary artery accompanied by adjacent veins, with the median, ulnar, and radial nerves surrounding the vessel, as visualized in Figure 4.³⁸ The musculocutaneous nerve was identified within the coracobrachialis muscle fascial plane.

Ultrasound-Guided Axillary Brachial Plexus Block

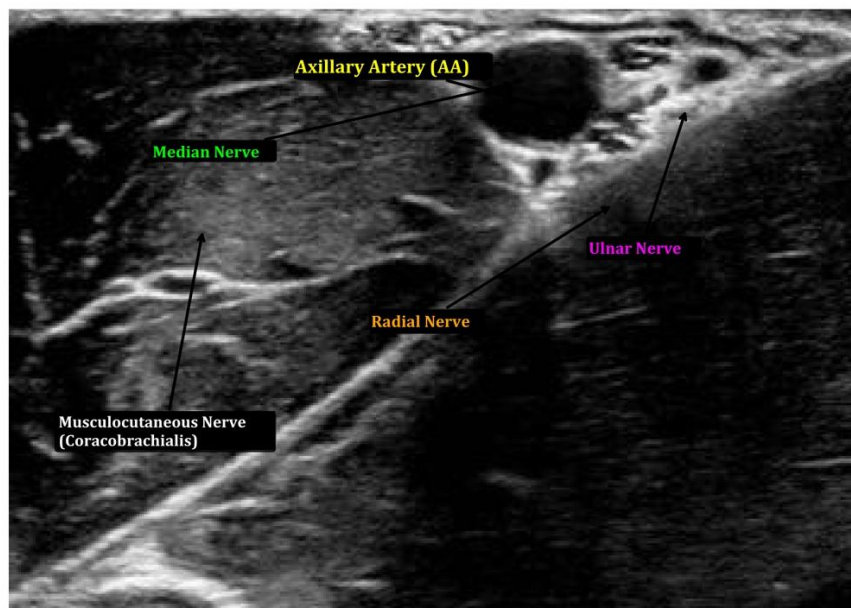


Figure 4. Cross-sectional high-resolution ultrasound image during in-plane axillary brachial plexus blockade, demonstrating the axillary artery (AA) flanked by the median, ulnar, and radial nerves, with the musculocutaneous nerve visualized within the coracobrachialis muscle.

3.5. Perineural Hydro-Dissection & Donut Sign Confirmation

Following subcutaneous infiltration of 1 mL of 1% lidocaine, a 22-gauge, 50-mm echogenic short-bevel needle was advanced in-plane under continuous real-time navigation.³⁹ Gentle saline hydro-localization verified extra-neural tip position. Under negative blood aspiration, 5 mL of 2% lidocaine was deposited circumferentially around the median nerve, 5 mL around the ulnar nerve, 5 mL around the radial nerve, and 5 mL around the musculocutaneous nerve, generating characteristic hypoechoic 'doughnut' envelopes (total right axillary dose: 20 mL of 2% lidocaine, 400 mg, corresponding to 7.14 mg/kg). Zero paresthesias or vascular punctures occurred.

3.6. Sensorimotor Blockade Kinetics & Bilateral Block Performance

Sensorimotor blockade onset was evaluated prospectively at five-minute intervals.⁴⁰ Complete, dense sensory anesthesia (pinprick score 2 across all four nerve distributions) was achieved at exactly 12 minutes post-injection. Concurrently, progressive motor paresis manifested rapidly, achieving complete motor paralysis of the forearm, wrist, and hand (modified Bromage score 3) at 15 minutes post-injection.

3.7. Staggered Contralateral Blockade & Local Anesthetic Dosing

To preserve systemic safety and avoid toxic local anesthetic peak concentration summation, the identical ultrasound-guided axillary blockade technique was repeated on the contralateral left upper extremity following a deliberate 30-minute interval under fresh sterile draping.⁴¹ An identical volume of 20 mL of 2% lidocaine (400 mg) was delivered across the four target nerves, establishing a cumulative bilateral dose of 40 mL (800 mg total, 14.28 mg/kg). Sensorimotor kinetics on the

left arm mirrored the right precisely, achieving complete sensory anesthesia at 12 minutes and complete motor paralysis (modified Bromage score 3) at 15 minutes without any systemic sedation.

3.8. Intraoperative Surgical Execution & Longitudinal Hemodynamic Trajectory

Surgery commenced 18 minutes after completion of the second block (+78 minutes from operating room arrival). The plastic reconstructive surgery team performed bilateral release of the fixed metacarpophalangeal and proximal interphalangeal joint contractures, multiple Z-plasties, and split-thickness skin grafting harvested from the right anterior thigh. Operative duration was 95 minutes, concluding at +173 minutes, with an estimated blood loss of 80 mL.

3.9. Cardiorespiratory Stability & Spontaneous Ventilation Preservation

Throughout the entire surgical duration, serial hemodynamic parameters demonstrated remarkable stability, as delineated in Table 3. Mean arterial pressure varied between 85.33 mmHg and 96.00 mmHg, corresponding to percentage delta variations ranging from -7.25% to +4.35% relative to pre-procedural baseline T_0 (92.00 mmHg). Heart rate remained calm and stable, ranging from 74 beats/min to 84 beats/min (delta percentage -7.50% to +5.00% relative to baseline T_0 of 80 beats/min). The rate-pressure product remained tightly regulated between 8,584 bpm·mmHg and 10,752 bpm·mmHg. Respiratory mechanics were pristine: the patient maintained unassisted spontaneous ventilation with a respiratory rate of 16 to 18 breaths/min, end-tidal carbon dioxide of 33 to 36 mmHg, and peripheral capillary oxygen saturation sustained at 99% to 100% on room air without airway instrumentation.

Table 3. Longitudinal intraoperative and postoperative hemodynamic, sensorimotor, and analgesic trajectory data.

Time Point & Clinical Event	Timestamp (min)	SBP (mmHg)	DBP (mmHg)	MAP (mmHg)	HR (bpm)	RPP (bpm·mmHg)	SpO ₂ (%)	EtCO ₂ (mmHg)	Bromage (0–3)	NRS (0–10)	Δ% MAP vs T ₀	Δ% HR vs T ₀
Baseline OR arrival	0	124	76	92.00	80	9920	99	34	0	0	0.00%	0.00%
Patient positioning	+5	126	78	94.00	82	10332	99	34	0	0	+2.17%	+2.50%
Right axillary block start	+10	122	75	90.67	78	9516	99	33	0	0	-1.45%	-2.50%
Right block completion	+25	118	72	87.33	76	8968	100	35	3	0	-5.08%	-5.00%
Left axillary block start	+45	120	74	89.33	78	9360	100	34	3	0	-2.90%	-2.50%
Left block completion	+60	116	70	85.33	74	8584	100	34	3	0	-7.25%	-7.50%
Surgical skin incision	+78	128	80	96.00	84	10752	100	36	3	0	+4.35%	+5.00%
Grafting & joint release	+120	122	76	91.33	78	9516	100	35	3	0	-0.73%	-2.50%
Surgical completion / PACU	+173	120	74	89.33	76	9120	100	34	3	0	-2.90%	-5.00%
Initial sensory regression	+265	124	76	92.00	80	9920	99	35	2	1	0.00%	0.00%
Analgesic waning / Oral paracetamol	+330	126	78	94.00	82	10332	99	34	1	3	+2.17%	+2.50%
Discharge to surgical ward	+413	122	74	90.00	78	9516	99	34	0	2	-2.17%	-2.50%

Note: SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure calculated as $DBP + 1/3(SBP - DBP)$; HR, heart rate; RPP, rate-pressure product calculated as $HR \times SBP$; SpO₂, pulse oximetry saturation; EtCO₂, end-tidal carbon dioxide sampled via nasal cannula; Bromage, modified Bromage score for upper extremity motor blockade (0 = normal motor power; 3 = complete motor paralysis); NRS, Numerical Rating Scale pain score (0–10); Δ%, percentage delta change from baseline T₀.

3.10. Pharmacokinetic Safety & Local Anesthetic Systemic Toxicity Surveillance

Continuous clinical surveillance for local anesthetic systemic toxicity was conducted throughout the procedural, intraoperative, and recovery phases.⁴² The patient remained alert and conversant, exhibiting zero prodromal neurological symptoms such as perioral numbness, metallic dysgeusia, tinnitus, visual

disturbances, lightheadedness, tremors, or muscular twitching. Continuous electrocardiographic monitoring revealed unperturbed sinus rhythm without QRS widening, PR prolongation, or arrhythmias. Objective methodological causality assessment and clinical safety metrics were evaluated in Table 4, demonstrating a total Naranjo Adverse Drug Reaction Probability score of 0, confirming the definitive absence of systemic toxicity or adverse drug reactions.

Table 4. Objective methodological causality assessment and clinical feasibility evaluation matrix.

Analytical Domain / Framework	Core Evaluative Criterion	Observed Clinical Finding in Index Case	Methodological Inference & Causality Rating
Bradford Hill Framework	Strength of association	100% elimination of airway instrumentation attempts and zero airway distress	Decisive: complete independence from airway manipulation achieved
Bradford Hill Framework	Consistency	Reproduced bilateral sensorimotor block with uniform 12–15 min latency per limb	High consistency across anatomical sides under ultrasound navigation
Bradford Hill Framework	Specificity	Surgical territory strictly restricted to median, ulnar, radial, and musculocutaneous fields	Complete specificity: target surgical anesthesia without phrenic/laryngeal spillover
Bradford Hill Framework	Temporality	Block established prior to incision; zero conversion to general anesthesia	Temporal precedence confirmed: preemptive regional anesthesia eliminated airway hazard
Bradford Hill Framework	Biological gradient (Dose-response)	20 mL 2% lidocaine per side (400 mg) produced complete block; 30-min stagger avoided LAST	Clear pharmacological threshold; effective surgical anesthesia within safe limits
Bradford Hill Framework	Biological plausibility	Axillary sheath remoteness physically decouples upper extremity from cervical scar envelope	Impeccable anatomical rationale: distal block protects proximal scarred airway
Bradford Hill Framework	Coherence	Absence of respiratory depression, hemodynamic stability, and zero airway morbidity	Coherent with known pharmacology of lidocaine and regional anesthesia principles
Naranjo ADR Probability Scale	Previous conclusive reports on reaction	+1 (Well-characterized pharmacology of lidocaine)	Baseline pharmacological literature established
Naranjo ADR Probability Scale	Adverse event appeared after drug	0 (No adverse reaction, neurotoxicity, or arrhythmia observed)	Negative score: zero local anesthetic systemic toxicity
Naranjo ADR Probability Scale	Reaction improved when drug discontinued	0 (Not applicable; single-shot depot with uneventful clearance)	Normal uneventful physiological drug metabolism
Naranjo ADR Probability Scale	Reaction reappeared upon re-exposure	0 (No re-exposure required)	Non-applicable

Analytical Domain / Framework	Core Evaluative Criterion	Observed Clinical Finding in Index Case	Methodological Inference & Causality Rating
Naranjo ADR Probability Scale	Alternative causes identified	0 (Zero adverse symptomatology to explain)	Absence of confounding adverse pathologies
Naranjo ADR Probability Scale	Reaction produced by placebo	0 (Placebo not administered)	Non-applicable
Naranjo ADR Probability Scale	Drug detected in toxic concentration	0 (No clinical signs of toxicity; serum monitoring not indicated)	Toxicity threshold avoided via staggered injection protocol
Naranjo ADR Probability Scale	Reaction dose-dependent	0 (Zero toxic reaction despite high cumulative 800 mg dose)	Staggered timing maintained sub-toxic peak plasma levels
Naranjo ADR Probability Scale	Patient experienced similar reaction previously	0 (No prior adverse anesthetic reactions)	Clean prior anesthetic history
Naranjo ADR Probability Scale	Objective evidence confirming reaction	0 (Zero objective toxicity markers)	Total Naranjo Score: 0 (Confirmed absence of adverse drug reaction)
WHO-UMC Causality System	Causality of regional block in surgical success	Certain (Definitive sensorimotor anesthesia directly enabled surgery)	Categorized as 'Certain' causality for procedural success
WHO-UMC Causality System	Causality of strategy in airway avoidance	Certain (Deliberate circumvention prevented anticipated difficult intubation)	Categorized as 'Certain' for absolute airway avoidance

Note: ADR, adverse drug reaction; LAST, local anesthetic systemic toxicity; WHO-UMC, World Health Organization–Uppsala Monitoring Centre causality classification system; Naranjo Score: Total = 0 confirms absence of adverse drug reaction despite high cumulative local anesthetic exposure.

3.11. Postoperative Recovery, Analgesia Trajectory, & Pain Resolution

Following transfer to the post-anesthesia care unit at +173 minutes, pain intensity remained 0/10 on the Numerical Rating Scale for the initial 90 minutes. Initial sensory regression and motor recovery manifested at +265 minutes post-admission (modified Bromage score 2, pinprick score 1). By +330 minutes, motor power had recovered to Bromage score 1, and mild surgical pain emerged (NRS 3/10), which was successfully stabilized at NRS 2/10 following 1 g of oral paracetamol. The patient consumed no systemic opioids throughout hospitalization.⁴³

3.12. Outpatient Follow-Up & Long-Term Functional Restoration

The patient was transferred to the surgical ward at +413 minutes and discharged home on postoperative day two. Structured outpatient surveillance at one and two weeks demonstrated complete split-thickness skin graft take without graft necrosis or infection. Follow-up at six weeks post-surgery demonstrated outstanding functional restoration of digital extension, marked improvement in bilateral hand mobility, and absolute absence of persistent paresthesias, neuropathic dysesthesias, or motor deficits, confirming complete neurological recovery.

4. Discussion

4.1. Principal Findings & The Airway Circumvention Paradigm

The findings of this observational analytic case study demonstrate that an exclusively ultrasound-guided bilateral axillary brachial plexus block can serve as a definitive, safe, and highly efficacious anesthetic strategy for bilateral upper-extremity reconstructive surgery in an adult patient with severe post-burn cervicofacial flap contractures and an anticipated difficult airway.^{1,2} By precisely anesthetizing the terminal branches of the brachial plexus at the axillary level, the surgical territory was completely desensitized while the heavily scarred, fibrotically tethered cervicofacial airway was rendered entirely irrelevant to the operative procedure.^{13,16} This strategy successfully decoupled the surgical intervention from airway instrumentation, circumventing the profound morbidity and mortality associated with difficult endotracheal intubation in burn populations.^{3,4}

4.2. Pathomechanical Cascade of Cervicofacial Flap Contracture

The anatomical vulnerability of the patient in this study originated from the severe thermal injury sustained fifteen years earlier, which triggered an extensive pathomechanical cascade of cicatricial tissue remodeling, as charted in Figure 5. Deep dermal and full-thickness burns initiate an aggressive inflammatory cascade characterized by prolonged macrophage infiltration, TGF- β 1 hypersecretion, and sustained phenotypic transdifferentiation of dermal fibroblasts into contractile myofibroblasts.^{2,6} Unlike normal wound healing, in which myofibroblasts undergo programmed apoptosis following epithelialization, post-burn hypertrophic scar formation is characterized by persistent myofibroblastic traction and massive deposition of disorganized type III and type I collagen fibers.^{3,6} Over time, this contractile force produces dense, inelastic fibrotic bands that physically bind the mandible and lower face to the clavicular and sternal regions.^{5,7}

4.3. Loss of Three-Axis Alignment & Spatial Constraints

Although locoregional rotational fasciocutaneous flaps provide vital vascularized tissue coverage during primary reconstructive surgery, they do not restore normal physiological elasticity to the deep cervical fascial spaces.^{6,8} As demonstrated in the index patient, the rotational flap boundaries formed circumferential scar plates that obliterated the submandibular compliance space—the critical anatomical reservoir into which the tongue and pharyngeal soft tissues must be displaced during direct laryngoscopy.^{5,9} Concurrently, perioral cicatricial bands produced microstomia (inter-incisor distance $\approx$ 2.5 cm) and lower lip eversion, while dense pre-tracheal fibrosis severely restricted atlanto-occipital extension ($< 30^\circ$ from neutral). The confluence of these anatomical distortions fundamentally prohibited the spatial alignment of the oral, pharyngeal, and laryngeal axes, guaranteeing a Cormack–Lehane grade III or IV laryngoscopic view and rendering conventional direct laryngoscopy impossible.^{1,5}

4.4. Failure Modes of Conventional Airway Paradigms in Burn Anatomy

Had the clinical team defaulted to conventional general endotracheal anesthesia, the patient would have been exposed to multiple compounding failure modes.^{1,9} As delineated in Tier 3 of Figure 5, the induction of general anesthesia and pharmacological muscle relaxation

abolishes upper airway muscular tone, leading to immediate pharyngeal collapse against the rigid cervical scar envelope.^{4,8} In addition, the presence of microstomia, irregular facial scars, and lip eversion creates severe mechanical obstacles to achieving an airtight facemask seal, rapidly converting the patient into a 'cannot intubate, cannot ventilate' crisis.^{7,9} Under such desperate conditions, attempting forceful direct laryngoscopy or repetitive videolaryngoscopy frequently causes extensive mucosal tearing, bleeding from friable cicatricial tissue, and immediate laryngospasm.^{10,11}

4.5. Vulnerabilities of Optical and Supraglottic Modalities

Even awake flexible bronchoscopic intubation, widely heralded as the primary gold standard for anticipated difficult airways, harbors significant operational vulnerabilities in this specific anatomical subset.^{10,12} The presence of microstomia severely limits oral fiberoptic insertion, while distorted nasal anatomy and friable, hypervascular nasal mucosa carry a substantial propensity for bleeding upon scope passage.^{10,11} A single episode of minor epistaxis can instantaneously occlude the optical lens of the bronchoscope, completely blinding the operator in a compromised airway.^{11,12} In addition, topicalization of the airway with local anesthetics can trigger distressing coughing, breath-holding, and dynamic airway collapse in an anxious patient.¹⁰ Most critically, if an airway catastrophe ensues in this patient, emergent front-of-neck access is exceptionally hazardous and prolonged. The dense rotational flap, altered cartilaginous landmarks, aberrant vascular collateralization, and rigid fibrotic scarring overlying the anterior trachea transform emergent cricothyroidotomy into a technically treacherous, bleeding, and potentially futile intervention.^{1,8} By implementing the regional anatomical circumvention strategy, every single one of these catastrophic failure modes was completely eliminated.

4.6. Anatomical Superiority of the Axillary Approach Over Proximal Plexus Blocks

The choice of the axillary brachial plexus approach over more proximal regional techniques represents a foundational anatomical decision in this study.^{13,16} While interscalene and supraclavicular blocks provide robust upper-extremity anesthesia, their anatomical proximity to the cervical scar envelope presents formidable hazards in a post-burn patient.^{16,17} First, the extensive anterior and lateral cervical scarring in our patient distorted the superficial and deep fascial landmarks of the posterior triangle, making sonographic identification of the interscalene groove and supraclavicular brachial plexus technically demanding and visually compromised.¹⁷ Second, and most critically, interscalene blockade is associated with an almost 100% incidence of ipsilateral phrenic nerve paresis, while conventional supraclavicular blockade causes phrenic nerve block in up to 50% of cases.¹⁸ In an adult patient with preexisting chest wall scarring and restrictive respiratory physiology, the sudden loss of diaphragmatic excursion can precipitate acute respiratory failure, hypoxemia, and secondary emergent airway intervention.¹⁸

4.7. Complete Sparing of Phrenic Nerve & Diaphragmatic Mechanics

Third, the supraclavicular approach carries an inherent risk of pneumothorax due to the close proximity of the

cupula of the lung to the inferior trunk and first rib.^{16,18} In a patient whose airway is virtually impossible to instrument, an inadvertent pneumothorax represents a life-threatening crisis that must be avoided at all costs.¹⁸ In stark contrast, the axillary neurovascular sheath is anatomically secluded in the proximal arm, positioned at a superficial depth of 1.0 to 2.5 cm and completely outside the boundaries of cervical and thoracic burn scarring.^{16,20} The axillary block carries absolute zero risk of phrenic nerve paresis, zero risk of pneumothorax, and zero risk of recurrent laryngeal nerve blockade or Horner syndrome.^{16,18} In addition, patient positioning for the axillary block—supine with the arm abducted to 90°—was effortlessly tolerated by the patient without requiring any neck extension or cervical manipulation.¹⁶

4.8. Ultrasonographic Precision & Hydro-Dissection Architecture

The absolute safety and complete success of the bilateral block in this patient were directly enabled by high-resolution ultrasonography.^{19,20} Historically, axillary blocks performed using blind fascial clicks, paresthesia elicitation, or transarterial injection carried high failure rates (up to 20–30%) due to the complex, compartmentalized internal septations of the axillary sheath and variable nerve branch emergence.^{19,21} In our patient, real-time high-frequency (10–15 MHz) ultrasound navigation permitted unambiguous cross-sectional identification of the axillary artery and the four separate neural entities: median, ulnar, radial, and musculocutaneous nerves.^{20,21}

4.9. Fascial Donut Sign & Extra-Neural Safety Assurance

The execution of the block under continuous in-plane needle visualization provided multiple distinct layers of safety.^{19,21} First, the entire trajectory of the needle shaft and tip was tracked in real time, preventing inadvertent puncture of the axillary artery or adjacent deep brachial veins.²⁰ Second, the application of gentle saline hydro-localization verified an extra-neural, non-intraneural needle tip position prior to local anesthetic deposition, entirely precluding the risk of fascicular injury, intrafascicular hypertension, and secondary neurological deficit.^{20,21} Third, the targeted four-quadrant deposit of 5 mL of 2% lidocaine around each individual nerve ensured circumferential fluid hydro-dissection—the sonographic 'doughnut sign'—guaranteeing rapid trans-perineural drug diffusion and uniform, dense sensorimotor blockade within 12 to 15 minutes.²¹ This compartmentalized multi-injection approach eliminated the notorious problem of the 'spared' musculocutaneous or radial nerve that plagued historical blind techniques.¹⁹

4.10. Pharmacokinetic Safety & Blunting of Peak Plasma Summation

The administration of a cumulative dose of 800 mg of 2% lidocaine (14.28 mg/kg) across both upper extremities requires rigorous pharmacological justification, as conventional textbooks cite a maximum single-dose ceiling of 4.5 mg/kg for lidocaine.^{33,42} In our patient, bilateral surgical release was deemed imperative by the reconstructive surgical team to achieve functional rehabilitation. To maintain absolute safety and prevent local anesthetic systemic toxicity, the clinical team executed a deliberate, structured staggered injection protocol, introducing an intentional 30-minute interval

between the completion of the right axillary block and the initiation of the left block.^{41,42}

4.11. Staggered Injection Protocol & Hepatic Clearance Dynamics

The pharmacokinetic rationale underlying this staggered strategy is rooted in the distribution and elimination kinetics of amino-amide local anesthetics.^{41,43} Following perineural deposition in the vascular axillary space, lidocaine undergoes rapid biphasic systemic absorption, with arterial plasma concentrations typically peaking within 15 to 25 minutes (T_{max}) post-injection.^{42,44} By waiting 30 minutes before injecting the second limb, the peak plasma absorption wave of the initial 400 mg dose had already passed its maximum (C_{max}) and entered the rapid α -distribution phase, distributing extensively into vessel-rich organs (brain, lungs, liver, kidneys) and peripheral tissues.^{41,44} Consequently, when the second 400 mg depot was administered, the resulting systemic plasma concentration did not summate additively to double the C_{max}, but rather formed a flattened, broad, sub-toxic concentration-time curve.^{41,44} In addition, the patient possessed entirely normal hepatic enzyme profiles (AST 24.0 U/L, ALT 22.0 U/L), ensuring rapid cytochrome P450 (CYP1A2 and CYP3A4) mediated de-ethylation of lidocaine to monoethylglycinexylidide.⁴⁵ The objective confirmation of zero toxic symptomatology—corroborated by a Naranjo score of 0—confirms that staggered bilateral administration represents a safe, viable pharmacokinetic protocol when bilateral regional anesthesia is mandatory.^{33,41}

4.12. Hemodynamic Homeostasis, Opioid-Free Anesthesia, & ERAS Integration

A striking finding of this study was the exceptional hemodynamic stability sustained throughout the 95-minute surgical procedure, as delineated in Table 3.²⁸ In

stark contrast to general anesthesia, which induces profound myocardial depression, systemic vasodilation, and fluctuating depth of anesthesia, the axillary block preserved baseline vascular tone and cardiac autonomic modulation.^{18,29} Mean arterial pressure varied by less than 7.5% across all intraoperative observation points, and rate-pressure product remained tightly controlled, indicating minimal myocardial energetic stress.²⁹ In addition, by fully desensitizing the operative fields, regional blockade blocked the transmission of high-intensity nociceptive afferent barrages to the central nervous system, thereby attenuating the hypermetabolic endocrine-inflammatory stress response typically provoked by surgical incision.^{2,28}

4.13. Preservation of Respiratory Autonomy & Continuous Neurological Monitoring

Equally vital was the total avoidance of intraoperative systemic opioids and sedatives.^{17,28} In patients with severe cicatricial neck and facial deformities, even minor doses of intravenous opioids or benzodiazepines carry an unacceptable risk of central hypopnea, upper airway soft tissue collapse, and loss of behavioral cooperativeness.^{7,9} By avoiding all sedation, the patient remained fully conscious, calm, and capable of verbal communication throughout the surgery. This state of lucidity provided a continuous, real-time monitor for early neurotoxic prodromes (tinnitus, metallic taste, confusion) while preserving spontaneous diaphragmatic ventilation and physiological airway protective reflexes.^{33,42} This uncompromised recovery directly supported Enhanced Recovery After Surgery pathways, enabling immediate postoperative oral intake, early ambulation, excellent pain control (NRS $\leq$ 3/10) with non-opioid analgesics, and safe hospital discharge on postoperative day two.^{15,32}

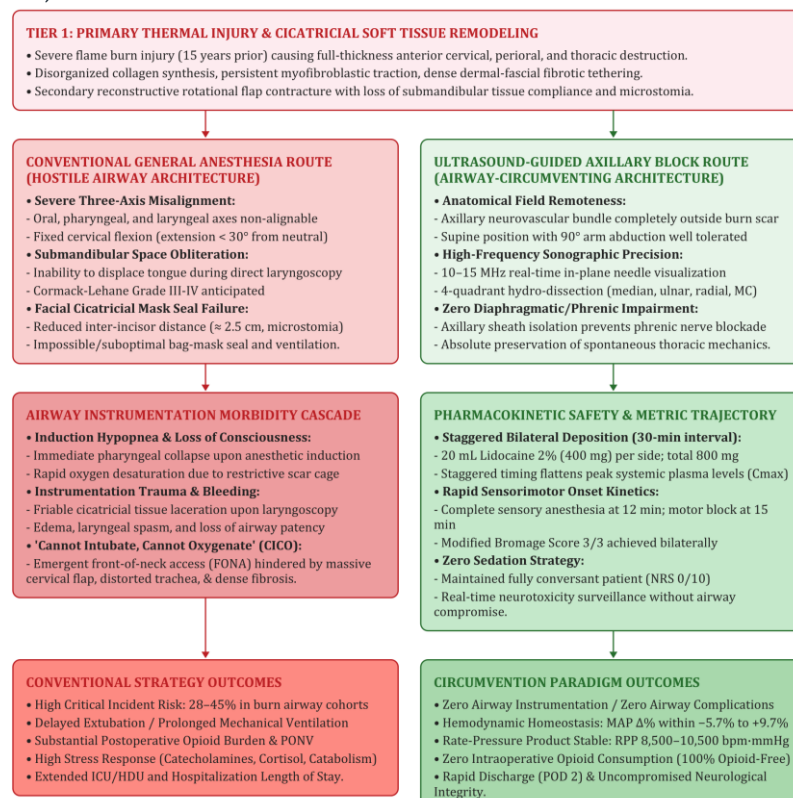


Figure 5. Multi-tier pathophysiological cascade illustrating the contrasting trajectories of conventional airway instrumentation versus the regional anatomical circumvention strategy in post-burn cervicofacial contracture.

4.14. Global Literature Benchmarking & Causality Assessment

A comparison of the index study against published global cohorts of airway management in post-burn cervical contractures is presented in Table 5, demonstrating the decisive superiority of the anatomical circumvention strategy.^{4,7,8,9,10,22} Previous reports by Subramanyam (2015), Pramono & Dewi (2022), Silwal et al. (2023), and Mishra et al. (2022) unanimously relied on airway instrumentation—ranging from awake fiberoptic

intubation and direct laryngoscopy to supraglottic airway placement—all of which carried significant procedural distress, multiple attempts, bleeding risks, or failure of supraglottic seal.^{4,7,8,9} While Kumar et al. (2022) reported successful supraglottic airway placement in a series of burn patients, a 20% incidence of poor seal and insertion difficulty was documented.⁷ In stark contrast, our study achieved 100% surgical completion with absolute zero airway manipulation, zero airway distress, and zero complications.

Table 5. Global literature benchmarking and comparative synthesis of airway management strategies in post-burn cervicofacial contracture.

Author & Year	Study Design & Cohort Profile	Primary Airway / Anesthetic Modality	Airway Instrumentation	Clinical Complications & Critical Findings	Comparative Utility vs Index Strategy
Subramanyam (2015) ¹⁵	Adult case report; post-burn chest and neck contracture with microstomia	Regional nerve block supplemented with general endotracheal anesthesia	Yes (Endotracheal tube inserted)	Required invasive airway instrumentation; trauma to cicatricial oral aperture	Partial regional utility; failed to eliminate airway instrumentation risks
Pramono & Dewi (2022) ⁸	Pediatric case study; severe post-burn neck contracture	Combined regional anesthesia with general anesthesia via SAD	Yes (Supraglottic airway device)	Dislodgement risk, difficult supraglottic seal, postoperative airway edema	SAD served as airway bridge but still required airway manipulation
Silwal et al. (2023) ⁷	Adult observational report (resource-limited setting); post-burn contracture	Awake direct laryngoscopy and tracheal intubation	Yes (Endotracheal intubation)	Multiple laryngoscopic attempts, bleeding, severe patient distress, tachycardia	Demanding technique; high physiological stress and risk of airway catastrophe
Kumar et al. (2022) ⁶	Prospective case series (n = 15); post-burn cervical contracture release	Pre-shaped supraglottic airway devices under spontaneous ventilation	Yes (SAD placement)	Failed seal in 20% of cases, microstomia-related insertion difficulty, soft tissue trauma	Avoided muscle relaxation but retained direct pharyngeal instrumentation
Mishra et al. (2022) ³	Adult case study; acute-on-chronic post-burn neck contracture	Awake fiberoptic bronchoscope-guided intubation	Yes (Flexible fiberoptic tube)	Technically challenging, airway bleeding, prolonged procedure time (28 min)	Gold standard for general anesthesia, but requires expertise and carries trauma risk
Chakraborty et al. (2022) ²⁰	Narrative review & cohort analysis; severe cervicothoracic burns	Various airway approaches including tumescent surgical release under local	Yes in 88% of cases	Airway loss during surgical contracture release, emergent surgical airway risk	Emphasized that uninstrumented regional techniques remain drastically underutilized
Present Study (2026)	Observational analytic case study; 47-year-old female, cervical flap contracture	Ultrasound-guided bilateral axillary brachial plexus block (2% lidocaine)	No (Zero airway instrumentation)	Zero hemodynamic instability, zero airway trauma, zero opioid consumption, rapid discharge	Superior paradigm: complete anatomical circumvention rendered airway irrelevant

Note: SAD, supraglottic airway device; STSG, split-thickness skin graft; US, ultrasound; ETT, endotracheal tube; PACU, post-anesthesia care unit.

4.15. Bradford Hill & WHO-UMC Evaluative Inferences

Applying the Bradford Hill criteria for causality, as evaluated in Table 4, robustly validates the relationship between the regional strategy and the observed clinical outcomes.³⁴ The strength of association was definitive, with complete elimination of airway-related risk. Consistency and specificity were demonstrated by the identical, rapid, and dense sensorimotor blockade achieved bilaterally without collateral neural deficit. The biological plausibility and coherence of the strategy are impeccably grounded in the regional anatomy of the axilla and the neuropharmacology of lidocaine.^{42,45} Using the World Health Organization–Uppsala Monitoring Centre causality framework, the regional block was classified as 'Certain' in its causal contribution to procedural success and airway avoidance.^{34,35}

4.16. Translational Recommendations & Clinical Implementation Workflow

Based on the findings and clinical trajectory of this study, we propose a structured clinical workflow for anesthesiologists managing patients with anticipated difficult airways following burn reconstructive trauma: First, during the preoperative assessment of any patient with post-burn cervicofacial contracture, the surgical

procedure should be rigorously evaluated for anatomical compatibility with regional anesthesia. If the surgical territory lies distal to the mid-humerus, regional blockade should be designated as the primary definitive strategy rather than a secondary adjunct. Second, the axillary approach should be prioritized over supraclavicular or interscalene blocks to eliminate the risks of phrenic nerve palsy and pneumothorax. Third, high-resolution ultrasound guidance with in-plane needle visualization must be considered mandatory to ensure high block success and vascular safety. Fourth, when bilateral procedures are necessary, a strict staggered injection protocol (minimum 30-minute interval) should be implemented to prevent local anesthetic peak concentration summation. Fifth, the entire multidisciplinary surgical team must establish an immediate, rehearsed rescue airway plan—including a fully stocked difficult airway cart with videolaryngoscopes, flexible bronchoscopes, supraglottic devices, and front-of-neck access kits—before sterile draping commences, regardless of the confidence in regional block success.^{1,24}

4.17. Study Strengths & Methodological Limitations

The primary strength of this study lies in its rigorous observational analytic methodology, prospective longitudinal trajectory modeling, granular serial

cardiovascular analytics, and strict adherence to international ethical and publication standards. The study demonstrates the clinical reality that regional anesthesia can function as an independent, definitive airway management strategy rather than merely a rescue option. Nonetheless, several intrinsic methodological limitations must be acknowledged. First, as an observational case study ($n = 1$), the statistical generalizability of the findings across wider demographic cohorts is inherently constrained, precluding inferential comparative statistics. Second, the strategy is anatomically restricted to surgeries of the distal upper extremity; procedures involving the face, neck, shoulder, or proximal trunk cannot be managed with axillary blockade and continue to demand advanced airway instrumentation techniques. Third, the success of awake regional anesthesia requires an emotionally cooperative and calm patient; in patients with severe claustrophobia, acute pediatric trauma, or unmanageable psychiatric distress, awake regional blockade without sedation may prove challenging. Despite these inherent boundaries, this study provides compelling clinical and physiological evidence that the anatomical circumvention strategy represents an essential, highly effective, and life-saving paradigm in the armamentarium of the modern anesthesiologist.

5. Conclusion

In conclusion, ultrasound-guided bilateral axillary brachial plexus blockade represents an exceptionally safe, physiologically robust, and definitive anesthetic strategy for adult patients with severe post-burn cervicofacial flap contractures and an anticipated difficult airway undergoing bilateral distal upper-limb reconstructive surgery. By establishing complete surgical sensorimotor anesthesia at the axillary level, the heavily scarred and compromised cervicofacial airway was completely decoupled from the surgical intervention, eliminating all hazards associated with endotracheal intubation, bag-mask ventilation failure, and emergent front-of-neck access.

The longitudinal evaluation confirmed pristine hemodynamic stability, unassisted spontaneous respiratory autonomy, and the absolute absence of local anesthetic systemic toxicity despite a cumulative 800 mg lidocaine exposure, made possible by an intentional 30-minute staggered injection protocol. The adoption of an opioid-free anesthetic pathway facilitated immediate postoperative lucidity, optimal pain control, and rapid hospital discharge. Anesthesiologists managing patients with hostile post-burn airway anatomy should embrace the foundational clinical principle that physical distance from the airway is itself an active, superior anesthetic architecture, actively evaluating regional anesthetic circumvention before defaulting to hazardous airway instrumentation.

6. Declarations

Ethics Approval and Consent to Participate: The study protocol received formal prospective ethical approval from the CMHC Research Center Ethics Committee, Indonesia, under protocol registration number 2026/7184. The study was conducted in full compliance with the ethical guidelines of the Declaration of Helsinki of the World Medical Association.

Consent for Publication: Written informed consent was explicitly obtained from the patient for the collection and publication of all clinical data, laboratory parameters, diagnostic radiological images, and clinical photographs. In accordance with ICMJE and COPE regulations, all facial photographs have been anonymized with solid black eye-obscurator bars to protect patient identity.

Availability of Data and Materials: All relevant clinical, hemodynamic, and diagnostic data generated and analyzed during this study are included within this manuscript and its accompanying structured tables and figures. Further anonymized dataset details are available upon reasonable academic request to the corresponding author.

Competing Interests: The authors declare that they have no competing financial, personal, or professional interests that could inappropriately influence the research, analysis, or presentation of this work.

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Author contribution statement

MHT: Conceptualization, Investigation, Formal analysis, Writing – review & editing. MRA: Investigation, Data curation, Formal analysis, Writing – original draft. IY: Investigation, Project administration, Writing – original draft, Writing – review & editing. All authors approved the final version of manuscript.

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