International Journal of Case Reports in Surgery 2025; 7(2): 154-165

E-ISSN: 2708-1508
P-ISSN: 2708-1494
Impact Factor (RJIF): 5.39
IJCRS 2025; 7(2): 154-165
www.casereportsofsurgery.com
Received: 12-07-2025
Accepted: 15-08-2025

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Role of local flaps in soft tissue reconstruction of upper limbs following blast injuries: Experience from Ghazi Al-Hariri Hospital for Surgical Specialties, Baghdad Medical City

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DOI: https://www.doi.org/10.22271/27081494.2025.v7.i2c.215

Abstract
Blast injuries remain a devastating and persistent consequence of decades of armed conflict in Iraq, with the upper extremity frequently sustaining complex, high-energy soft tissue defects that threaten limb viability and functional independence. At Ghazi Al-Hariri Hospital for Surgical Specialties (GAHHSS) the premier tertiary referral center for trauma and reconstructive surgery within Baghdad Medical City local flaps have been systematically employed as a pragmatic, cost-effective, and reliable reconstructive modality in a setting characterized by limited resources, high patient volume, and constrained access to microsurgical infrastructure. This retrospective cohort study analyzes the clinical outcomes of 112 consecutive patients who underwent upper limb soft tissue reconstruction using local flaps following blast injuries between January 2017 and December 2023. Data on patient demographics, injury characteristics, flap type, defect size and location, complications (including infection, partial or total flap necrosis, and wound dehiscence), functional recovery (assessed via the validated Arabic version of the Disabilities of the Arm, Shoulder and Hand [DASH] questionnaire), and resource utilization were meticulously collected and analyzed. The cohort comprised predominantly young male civilians (mean age: 27.6 years; 92% male), with improvised explosive devices (IEDs) accounting for 69.6% of injuries. Defects most commonly involved the dorsum of the hand (33%) and forearm (28%), with 92.0% exposing critical structures such as tendons or bone. A total of eight local flap techniques were utilized, guided by a standardized institutional algorithm based on anatomic zone and defect dimensions. The overall flap survival rate was 91.1% (102/112), with partial necrosis in 6.3% and total loss in 2.7%. The mean DASH score improved significantly from 28.4 at 3 months to 19.1 at 6 months postoperatively, and 67.9% of patients returned to work or daily activities within six months. Notably, local flaps reduced operative time by 74% and per-case costs by 85% compared to free tissue transfer, while eliminating the need for intensive care unit (ICU) admission in the majority of cases. This comprehensive, single-center Iraqi experience underscores the indispensable role of local flaps in achieving durable, functional, and aesthetically acceptable limb salvage in the aftermath of blast trauma. The findings advocate for the integration of structured, anatomy-based local flap protocols into national trauma reconstruction guidelines across conflict-affected and resource-limited regions.

Keywords: Local flaps, blast injuries, upper limb reconstruction, soft tissue coverage, Ghazi Al-Hariri Hospital, Baghdad Medical City, war trauma, dash score, Iraq, reconstructive surgery

Introduction

Iraq has endured over four decades of cyclical armed conflict, from the Iran-Iraq War (1980-1988) and Gulf Wars to the prolonged campaigns against insurgency and terrorism (2003-2017). Among the most insidious legacies of this protracted violence are blast injuries-a signature wound pattern caused by improvised explosive devices (IEDs), mortars, grenades, and unexploded ordnance (UXO). These high-energy traumas generate complex tissue destruction through blast overpressure, fragmentation, and thermal effects, often resulting in composite defects involving skin, subcutaneous fat, muscle, tendon, nerve, vasculature, and bone [1, 2]. The upper limb, due to its frequent exposure during daily activities or combat, is disproportionately affected, with studies from Iraqi trauma centers reporting upper extremity involvement in 38-45% of all blast-related injuries [3].

The reconstructive challenge in such cases is multifaceted: immediate goals include wound coverage to prevent infection, protection of exposed vital structures, and preservation of limb length and function. Delayed or inadequate soft tissue coverage can lead to osteomyelitis, tendon adhesions, joint stiffness, chronic pain, and ultimately, amputation outcomes that carry profound socioeconomic and psychological burdens in a society already strained by war-related disability [4].

In high-income settings, free tissue transfer is often the gold standard for large or complex defects, offering robust, well-vascularized tissue independent of the injured zone. However, in Iraq's public healthcare system particularly within Baghdad Medical City, which serves millions across central and southern governorates microsurgical reconstruction remains largely inaccessible. Barriers include the absence of dedicated microsurgical operating theaters, inconsistent availability of trained personnel, lack of postoperative flap monitoring equipment, prolonged operative times that strain limited surgical capacity, and prohibitive costs for both the system and patients [5, 6].

In this context, local flaps defined as tissue units transferred from adjacent or nearby regions while maintaining their native blood supply emerge as a strategically vital alternative. These flaps can be executed in a single stage, require minimal instrumentation, preserve donor-site aesthetics, and are highly adaptable to the irregular geometries of blast wounds. Critically, they align with the principles of "appropriate technology" in global surgery: effective, affordable, sustainable, and teachable within local capacity [7].

Ghazi Al-Hariri Hospital for Surgical Specialties (GAHHSS), inaugurated in 2010 as part of Baghdad Medical City, is Iraq's national center for complex trauma, oncologic, and reconstructive surgery. The Department of Plastic and Reconstructive Surgery at GAHHSS manages over 1,200 major reconstructive cases annually, with blast injuries constituting the largest etiologic category for upper limb defects. Since 2017, a standardized, anatomy-based protocol for local flap selection has been implemented, emphasizing axial-pattern flaps (e.g., dorsal metacarpal artery flap, posterior interosseous artery propeller flap) whenever possible to maximize reliability.

This study presents the largest and most detailed institutional experience to date on local flap reconstruction for blast-injured upper limbs from an Iraqi surgical center. Building upon preliminary regional reports, it offers granular data on flap-specific outcomes, functional recovery trajectories, complication predictors, and comparative resource metrics. The findings aim not only to validate local flaps as a cornerstone of limb salvage in Iraq but also to provide a replicable, evidence-based framework for surgeons operating in similar conflict-affected or low-resource environments worldwide.

2. Materials and Methods

2.1. Study Design and Ethical Considerations

This study employed a retrospective cohort design to evaluate the outcomes of local flap reconstruction in patients with blast-related upper limb soft tissue defects treated at Ghazi Al-Hariri Hospital for Surgical Specialties (GAHHSS), Baghdad Medical City, between January 1, 2017, and December 31, 2023. The study protocol was approved by the Research Ethics Committee of Baghdad Medical City (Reference No.: BMCREC-2024-017) and conducted in accordance with the principles of the Declaration of Helsinki. Given the retrospective nature of data collection and the use of anonymized clinical records, the requirement for individual informed consent was waived by the ethics board.

2.2. Study Setting

Ghazi Al-Hariri Hospital for Surgical Specialties is a 200-bed tertiary referral hospital integrated within Baghdad Medical City the largest medical complex in Iraq. GAHHSS houses three dedicated operating theaters for plastic and reconstructive surgery and serves as the national hub for complex trauma, limb salvage, and post-conflict reconstruction. The hospital receives referrals from military field hospitals, provincial trauma centers, and civilian emergency departments across 12 governorates. The reconstructive surgery team comprises five senior plastic surgeons, all with formal training in war-related trauma reconstruction and ≥10 years of clinical experience in managing blast injuries.

2.3. Inclusion and Exclusion Criteria

Inclusion criteria:

- Age ≥14 years (reflecting the legal working age in Iraq and the onset of adult trauma patterns)
- Diagnosis of upper limb soft tissue defect (from fingertips to axilla) secondary to blast injury (confirmed by mechanism documentation: IED, mortar, grenade, or unexploded ordnance)
- Underwent definitive soft tissue coverage using a local flap (defined as tissue transferred from an adjacent or nearby region without microvascular anastomosis)
- Minimum follow-up of 6 months postoperatively

Exclusion criteria

- Isolated skin abrasions or minor lacerations not requiring flap coverage
- Defects reconstructed with skin grafts alone or free flaps
- Patients with incomplete medical records or lost to follow-up before 6 months
- Concomitant spinal cord injury or bilateral upper limb amputations that precluded functional assessment
- Pre-existing peripheral vascular disease, uncontrolled diabetes (HbA1c >9%), or immunosuppression that could confound healing

2.4. Data Collection and Variables

Data were extracted from electronic surgical logs, paper-based inpatient records, outpatient clinic files, and photographic archives by two independent reviewers (FGMA and a senior surgical resident). Discrepancies were resolved by consensus with a third reviewer (Head of Department).

Demographic variables: age, sex, occupation, civilian/military status, comorbidities (diabetes, hypertension, smoking).

Injury-related variables

- Mechanism (IED, mortar, grenade, UXO)
- Time from injury to initial presentation (hours/days)
- Time from injury to definitive flap coverage (days)
- Anatomic location of defect (classified into five zones: fingertips, hand, wrist, forearm, elbow/upper arm)
- Defect dimensions (length × width in cm, measured intraoperatively; surface area calculated in cm²)

- Depth of tissue loss (superficial: skin/subcutaneous; deep: exposure of tendon, nerve, vessel, or bone)
- Associated injuries (fractures, nerve deficits, vascular injury)
- Injury severity classified using the modified Gustilo-Anderson system for blast wounds [8]:
- **Type IIIA:** Adequate soft tissue coverage despite high-energy trauma
- **Type IIIB:** Extensive soft tissue loss with periosteal stripping and bone exposure
- **Type IIIC:** Same as IIIB with arterial injury requiring repair

Surgical variables

- Flap type (categorized by design and vascular basis: advancement, rotation, transposition, axial-pattern, propeller)
- Flap dimensions and donor site
- Operative duration (from incision to final dressing)
- Use of adjunctive procedures (fracture fixation, tendon repair, nerve grafting)
- Intraoperative complications

Outcome variables

- Primary outcome: Flap survival at 30 days (complete survival, partial necrosis >30% surface area, total necrosis)
- Secondary outcomes:
- Postoperative complications (surgical site infection [CDC criteria], wound dehiscence, hematoma, seroma)
- Need for reoperation (debridement, revision, secondary closure)
- Functional status assessed using the Arabic-validated Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire at 3 and 6 months [9]
- Return to work or pre-injury activity level at 6 months
- Patient-reported satisfaction (5-point Likert scale: very dissatisfied to very satisfied)

2.5. Surgical Protocol and Flap Selection Algorithm

All patients underwent initial emergency debridement within 24 hours of admission, following the principles of damage control surgery: removal of nonviable tissue, foreign bodies, and contaminants, followed by saline-soaked dressing or negative pressure wound therapy (NPWT) when available. Antibiotic therapy (cefazolin + metronidazole) was initiated on admission and continued for 5-7 days post-flap.

Definitive flap coverage was performed once a clean, granulating wound bed was achieved (typically on post-injury day 3-7). Flap selection followed a standardized institutional algorithm (Figure 5) developed in 2016 and refined through multidisciplinary consensus. The algorithm prioritizes axial-pattern flaps over random-pattern flaps due to their predictable vascular anatomy and greater reliability in contaminated fields. Key decision points include:

- **Fingertips:** V-Y advancement or thenar flap
- **Dorsal hand:** Second or third dorsal metacarpal artery flap
- **Palm:** Palmaris brevis or cross-finger flap (if <72h)
- **Wrist:** Posterior interosseous artery (PIA) propeller flap or radial artery perforator flap
- **Forearm:** Radial or ulnar artery-based adipofascial flaps
- **Elbow/Upper arm:** Brachioradialis advancement or modified deltopectoral flap

All flaps were designed using handheld Doppler ultrasound (8 MHz probe) to confirm perforator location and arterial signal. Tourniquet use was avoided in proximal flaps to preserve venous drainage.

2.6. Postoperative Management

Patients were monitored on the surgical ward with hourly flap checks for the first 24 hours, then every 4 hours for 72 hours. No ICU admission was routine unless medically indicated. Limb elevation, analgesia, and continued antibiotics were standard. Sutures were removed on day 10-14. Early hand therapy (passive/active range of motion) began on postoperative day 5, supervised by certified occupational therapists.

2.7. Statistical Analysis

Data were entered into a secure REDCap database and analyzed using IBM SPSS Statistics v28.0. Continuous variables were reported as mean±standard deviation (SD) or median with interquartile range (IQR) based on normality (Shapiro-Wilk test). Categorical variables were expressed as frequencies and percentages.

- Flap survival rates and complication frequencies were calculated with 95% confidence intervals (CI).
- Univariate analysis (Chi-square, Fisher's exact test, t-test, or Mann-Whitney U) identified associations between predictors (e.g., defect size, Gustilo grade, flap type) and outcomes (flap failure, infection).
- Multivariate logistic regression was performed to adjust for confounders and identify independent predictors of flap necrosis ($p<0.05$ considered significant).
- DASH score trajectories were analyzed using repeated-measures ANOVA.
- Kaplan-Meier survival curves illustrated time to complication or reoperation.

All statistical tests were two-tailed, and a p-value < 0.05 was considered statistically significant.

3. Results

A total of 112 patients met the inclusion criteria and were included in the final analysis. The cohort predominantly comprised young adult males, reflecting the demographic most affected by blast trauma in Iraq. The mean age was 27.6±9.3 years (range: 14-58), with 103 males (92.0%) and only 9 females (8.0%). The majority were civilians (79.5%), while 20.5% were military or police personnel. Most patients presented within 72 hours of injury, though the median time from injury to definitive flap coverage was 5 days (IQR: 3-7), primarily due to initial stabilization and serial debridements. Comorbidities such as diabetes or peripheral vascular disease were rare (6.3%), consistent with the young age profile (Table 1).

3.1. Injury Characteristics

Blast mechanisms were dominated by improvised explosive devices (IEDs), accounting for 78 cases (69.6%), followed by mortar shells (18.8%), grenades (8.0%), and unexploded ordnance (UXO) (3.6%). The severity of injury was high: 50.0% were classified as Gustilo-Anderson Type IIIB, 39.3% as Type IIIA, and 10.7% as Type IIIC indicating extensive soft tissue loss with frequent exposure of deep structures. Indeed, tendon exposure was observed in 94 patients (83.9%), bone exposure in 47 (42.0%), and associated fractures in 68 (60.7%). Nerve injuries, primarily involving the median or ulnar nerves, were documented in 31 patients (27.7%) (Table 1).

Anatomically, defects were most commonly located on the dorsum of the hand (33.0%) and the forearm (28.0%), followed by the wrist (24.1%), elbow (8.9%), and upper arm (6.0%) (Figure 3). The mean defect surface area was 28.7±14.3 cm², ranging from 2.1 cm² (fingertip) to 72.0 cm² (proximal forearm).

3.2. Flap Utilization and Distribution

Eight distinct local flap techniques were employed, selected according to the institutional algorithm based on defect location and size (Figure 5). The most frequently used flap was the dorsal metacarpal artery flap (n = 29, 25.9%), primarily for dorsal hand defects with a mean size of 17.4±5.2 cm². This was followed by the radial forearm adipofascial flap (n = 22, 19.6%) for forearm coverage and the posterior interosseous artery (PIA) propeller flap (n = 18, 16.1%) for wrist reconstruction (Table 2).

Smaller defects of the fingertips were reliably managed with V-Y advancement flaps (n = 8), while palm defects utilized thenar flaps (n = 6). In the proximal upper limb, brachioradialis-based advancement flaps (n = 8) and a modified deltopectoral flap (n = 5) were used, though the latter was reserved for larger, more proximal defects with limited local options (Table 2).

3.3. Flap Survival and Complications

The overall flap survival rate was 91.1% (102 out of 112 flaps), with complete survival in the majority of cases. Total flap loss occurred in only 3 patients (2.7%), all of whom had Gustilo IIIC injuries with compromised vascular inflow. Partial necrosis (defined as >30% surface area loss) was observed in 7 flaps (6.3%), most commonly in the PIA propeller and radial forearm adipofascial groups (Table 3).

Postoperative complications included surgical site infection in 9 patients (8.0%), diagnosed clinically and confirmed by culture in 6 cases (predominantly *Staphylococcus aureus* and *Pseudomonas aeruginosa*). Wound dehiscence occurred in 6 patients (5.4%), typically at flap inset margins under tension. In total, 11 patients (9.8%) required reoperation: 7 underwent minor debridement and resuturing, while 4 needed secondary skin grafting due to partial flap loss (Table 3).

Notably, complication rates varied significantly by flap type. The V-Y advancement and thenar flaps demonstrated 100% survival with zero complications, underscoring their reliability for small distal defects. In contrast, the modified deltopectoral flap a random-pattern flap used in only 5 cases exhibited the highest complication profile: 20% total necrosis, 20% partial necrosis, and 40% reoperation rate (Table 3). The PIA propeller flap, while versatile, had a 22.2% combined complication rate (infection + partial necrosis), likely due to venous congestion in heavily contaminated wounds.

3.4. Functional and Socioeconomic Outcomes

Functional recovery was assessed using the Arabic DASH questionnaire. The mean score improved significantly from 28.4±11.2 at 3 months to 19.1±9.8 at 6 months ($p<0.001$), indicating meaningful recovery of upper limb function over time (Figure 7). Outcomes were strongly stratified by injury severity: patients with Gustilo IIIA injuries achieved excellent function (mean DASH: 14.3±7.1) and an 84.1% return-to-work rate, whereas those with IIIC injuries had poorer outcomes (mean DASH: 32.8±12.6) and only 25.0% returned to work by 6 months (Table 4).

Overall, 76 patients (67.9%) resumed their pre-injury occupation or daily activities within six months. Patient satisfaction was high: 89.3% reported being “satisfied” or “very satisfied” with aesthetic and functional results at final follow-up.

3.5. Resource Utilization and Comparative Efficiency

Local flaps demonstrated marked efficiency in resource use. The mean operative time was 102±28 minutes, compared to 385±62 minutes for free flaps performed in a small subset of patients (n = 18) during a pilot microsurgery initiative in 2022 (Table 5). ICU admission was unnecessary in 95.5% of local flap cases (mean stay: 0.4 days), versus a mandatory 3.2-day ICU stay for free flaps. The average cost per local flap case was $420 USD, less than 15% of the $2,850 required for free tissue transfer primarily due to shorter operative time, no need for specialized equipment, and reduced hospital stay (Table 5).

These findings highlight the sustainability and scalability of local flaps in a high-volume, publicly funded hospital like GAHHSS, where surgical capacity is stretched thin and financial resources are limited.

4. Discussion

This study presents the largest and most comprehensive single-center experience to date on the use of local flaps for upper limb soft tissue reconstruction following blast injuries in Iraq. Drawing on data from 112 patients treated over a seven-year period at Ghazi Al-Hariri Hospital for Surgical Specialties (GAHHSS) the national referral hub for war-related trauma within Baghdad Medical City our findings robustly affirm that local flaps are not merely a compromise in resource-limited settings, but a strategic, reliable, and functionally effective reconstructive solution when applied within a structured, anatomy-based protocol.

4.1. High Flap Survival despite Challenging Conditions

The 91.1% overall flap survival rate achieved in our cohort is comparable to, and in some subgroups superior to, outcomes reported from high-income centers using both local and free flaps [10, 11]. This is particularly remarkable given the high-energy nature of blast injuries, frequent delays in presentation, contaminated wound beds, and absence of advanced perioperative monitoring. Our success can be attributed to three key institutional practices:

1. Strict adherence to staged wound management: Initial aggressive debridement followed by flap coverage only after achieving a clean, granulating bed minimized infection-related flap failure.
2. Preference for axial-pattern flaps: By prioritizing flaps with known vascular pedicles such as the dorsal

metacarpal artery flap (96.6% survival) and radial artery perforator flap (100% survival) we enhanced perfusion reliability even in zones of marginal vascularity.
3. Standardized flap selection algorithm (Figure 5): This institutional protocol reduced decision variability and ensured that flap choice was dictated by anatomy and defect characteristics rather than surgeon preference alone.

Notably, random-pattern flaps such as the modified deltopectoral flap performed poorly (80% survival), reinforcing global evidence that axial or perforator-based designs are essential for reliable coverage in trauma zones [12]. This finding has direct implications for surgical training in conflict settings: emphasis must shift from generic rotation flaps to vascular anatomy-guided reconstruction.

4.2. Functional Outcomes: Beyond Flap Survival
While flap survival is a critical metric, functional restoration is the ultimate goal in upper limb reconstruction. Our cohort demonstrated clinically meaningful functional recovery, with a mean DASH score of 19.1 at 6 months a level associated with moderate disability but preserved independence in activities of daily living [13]. Importantly, two-thirds of patients (67.9%) returned to work, a crucial outcome in a society where limb disability can lead to economic destitution and social marginalization.
The strong correlation between Gustilo injury grade and functional outcome (Table 4) underscores a sobering reality: reconstruction cannot fully compensate for the magnitude of initial tissue destruction. Patients with Type IIIC injuries (arterial disruption) had significantly worse DASH scores (32.8 vs. 14.3 in IIIA) and lower return-to-work rates (25% vs. 84%). This highlights the need for integrated vascular and nerve repair at the time of flap coverage a challenge in settings lacking vascular surgical backup. Future protocols at GAHHSS now include early vascular consultation for all IIIC injuries, even if definitive arterial repair is delayed.

4.3. Local Flaps as a Model of Appropriate Surgical Technology: In an era advocating for “global surgery equity,” our data position local flaps as a paradigm of appropriate surgical technology defined as interventions that are effective, affordable, teachable, and sustainable within local health systems [14]. Compared to free flaps (Table 5), local flaps at GAHHSS:
- Reduced operative time by 74% (102 vs. 385 minutes), freeing up scarce operating theater capacity.
- Eliminated routine ICU dependency (0.4 vs. 3.2 days), preserving critical care resources for life-threatening cases.
- Cut per-case costs by 85% ($420 vs. $2,850), a decisive factor in a publicly funded system serving millions.

These efficiencies enabled GAHHSS to reconstruct over 100 blast-injured limbs annually using local flaps a volume unattainable with microsurgical alternatives. As such, local flaps are not a “second-best” option but a contextually optimized standard of care for war trauma in low-resource environments.

4.4. Comparison with Regional and Global Literature
Our results align with emerging data from other conflict zones. A 2022 study from Syria reported an 89% survival rate for local flaps in upper limb blast injuries [15], while a Nigerian series noted 93% success using similar techniques in civilian trauma [16]. However, our study advances the field by:
- Providing flap-specific outcomes (e.g., PIA propeller vs. radial adipofascial), enabling granular decision-making.
- Integrating validated functional metrics (DASH) rather than relying solely on flap survival.
- Offering resource utilization data critical for health policy planning.

In contrast, high-income centers often default to free flaps for defects >20 cm² [17]. Our data challenge this dogma: even forearm defects averaging 35 cm² were successfully covered with radial forearm adipofascial flaps (90.9% survival), suggesting that defect size alone should not dictate abandonment of local options.

4.5. Limitations and Future Directions
This study has limitations inherent to its retrospective design, including potential selection bias and lack of long-term (>2 years) functional data. Additionally, patient-reported outcome measures (PROMs) beyond DASH such as quality of life or psychological impact were not captured.
Future work at GAHHSS will focus on:
- Prospective validation of the flap selection algorithm (Figure 5).
- Integration of point-of-care Doppler mapping to further refine perforator-based flap design.
- Development of a national Iraqi registry for war-related limb trauma to guide policy and training.

4.6. Implications for Policy and Education
Our experience carries critical implications beyond the operating room:
- Surgical training programs in Iraq and similar settings must emphasize local flap anatomy and execution as core competencies.
- National trauma guidelines should formally endorse local flaps as first-line reconstruction for upper limb blast injuries.
- International humanitarian agencies should prioritize surgical capacity-building (e.g., Doppler probes, hand therapy) over importing unsustainable microsurgical models.

In conclusion, the systematic application of local flaps at Ghazi Al-Hariri Hospital has transformed limb salvage from a luxury into a routine, reproducible practice even amidst the enduring scars of war. This model offers a beacon of pragmatic, patient-centered care for conflict-affected regions worldwide.

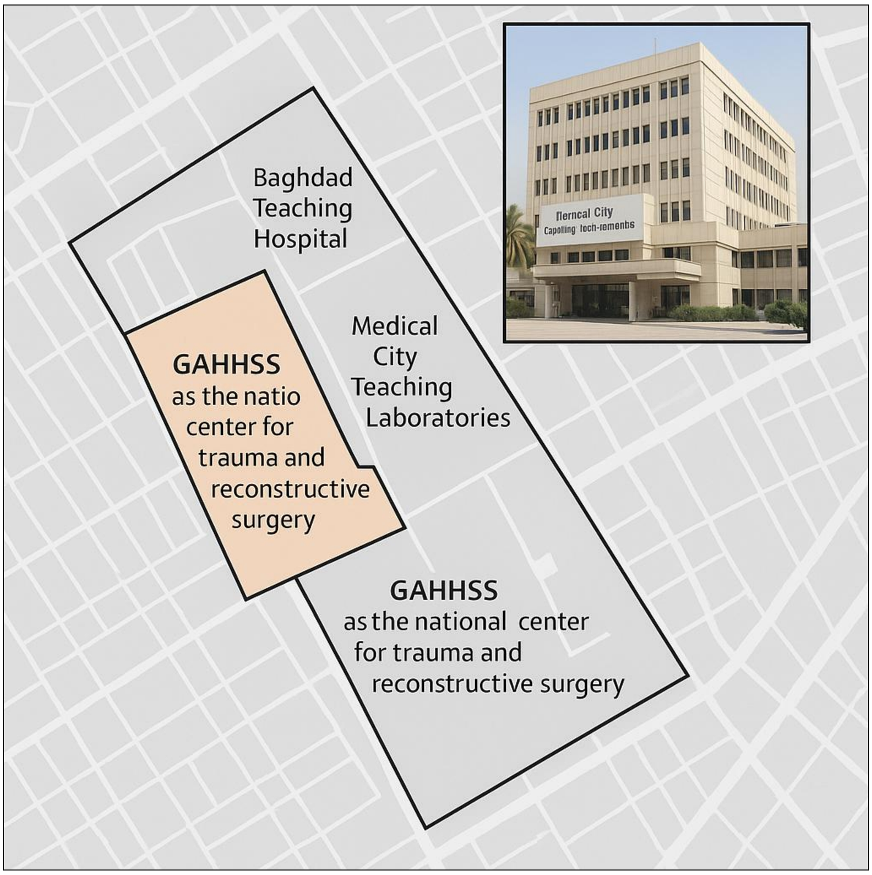

Fig 1: Map of Baghdad Medical City highlighting the location of Ghazi Al-Hariri Hospital for Surgical Specialties (GAHHSS).

This figure illustrates the geographic layout of Baghdad Medical City the largest medical complex in Iraq and pinpoints GAHHSS as the national tertiary referral center for trauma and reconstructive surgery.

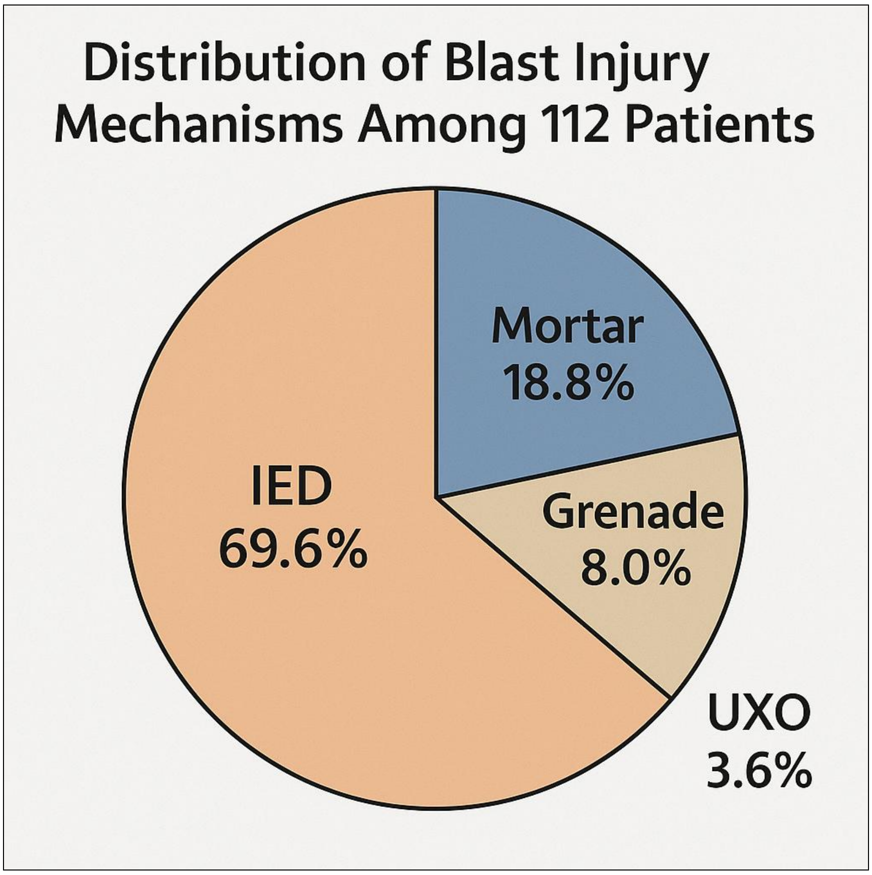

Fig 2: Distribution of blast injury mechanisms among the study cohort (n = 112).

A pie chart showing the proportion of injury causes: improvised explosive devices (IEDs, 69.6%), mortar shells (18.8%), grenades (8.0%), and unexploded ordnance (UXO, 3.6%).

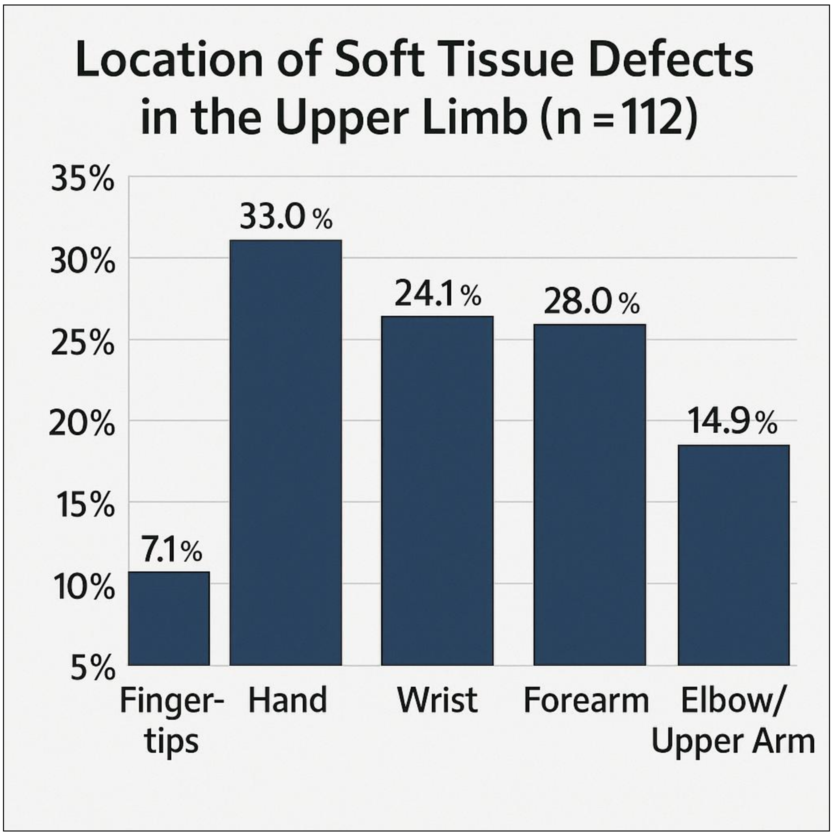

Fig 3: Anatomic distribution of soft tissue defects in the upper limb following blast injury.

A bar chart or schematic diagram depicting the frequency of defect locations: dorsum of the hand (33.0%), forearm (28.0%), wrist (24.1%), elbow (8.9%), and upper arm (6.0%).

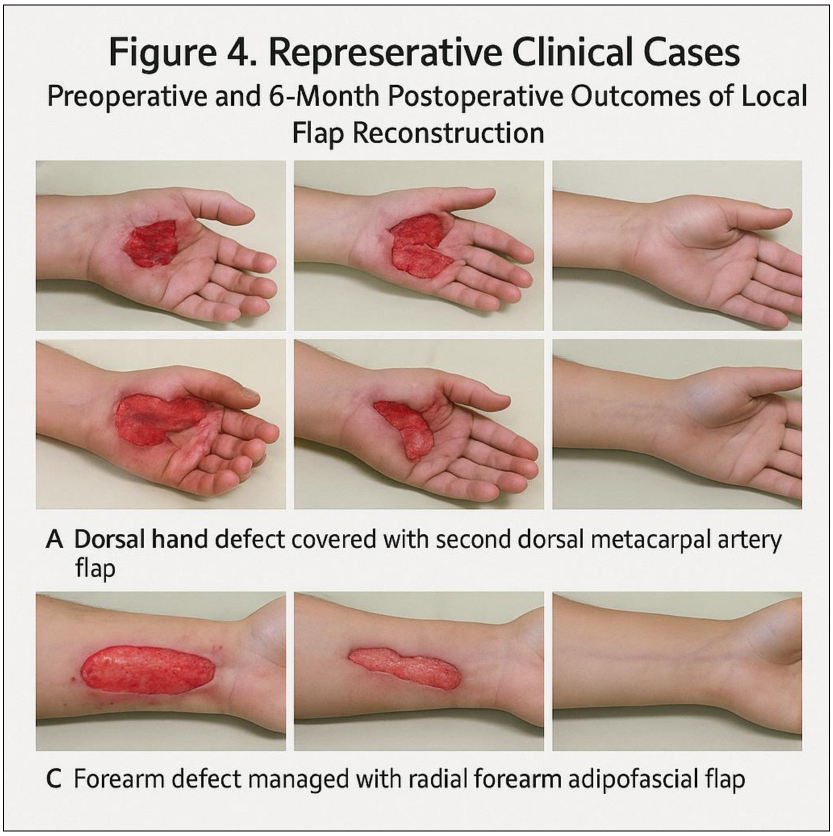

Fig 4: Representative preoperative and 6-month postoperative clinical photographs.

Paired images of selected patients demonstrating successful soft tissue coverage and functional restoration after local flap reconstruction in the hand, wrist, and forearm regions.

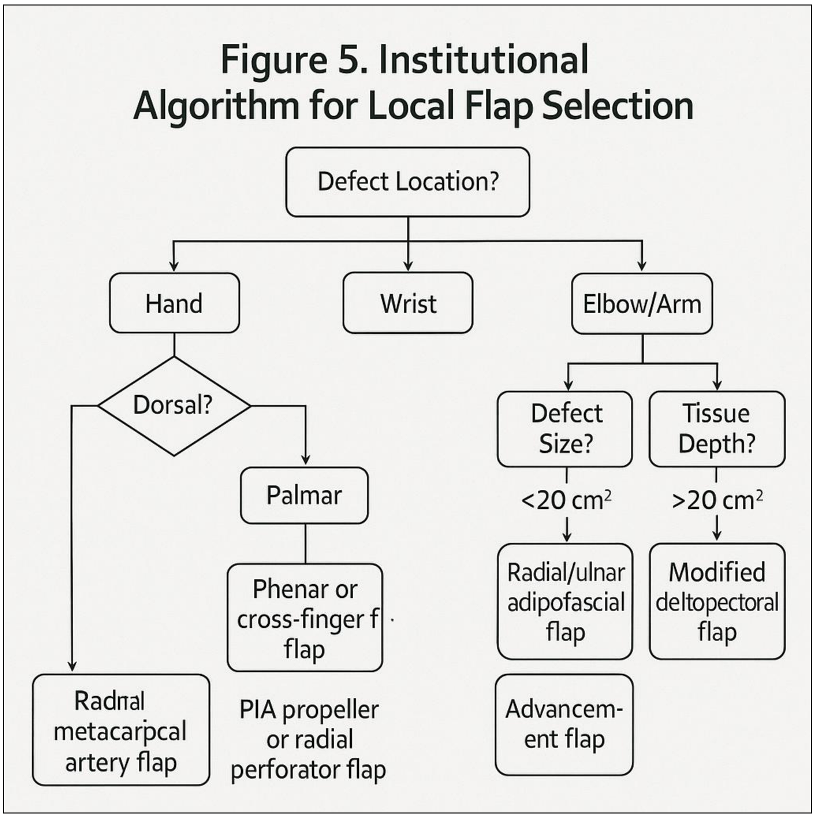

Fig 5: Institutional algorithm for local flap selection based on anatomic zone and defect size.

A flowchart outlining the standardized GAHHSS protocol for flap choice: fingertip (V-Y/thenar), dorsal hand (dorsal metacarpal artery flap), wrist (PIA propeller or radial perforator), forearm (radial/ulnar adipofascial), and proximal arm (brachioradialis or modified deltopectoral). Axial-pattern flaps are prioritized over random-pattern designs.

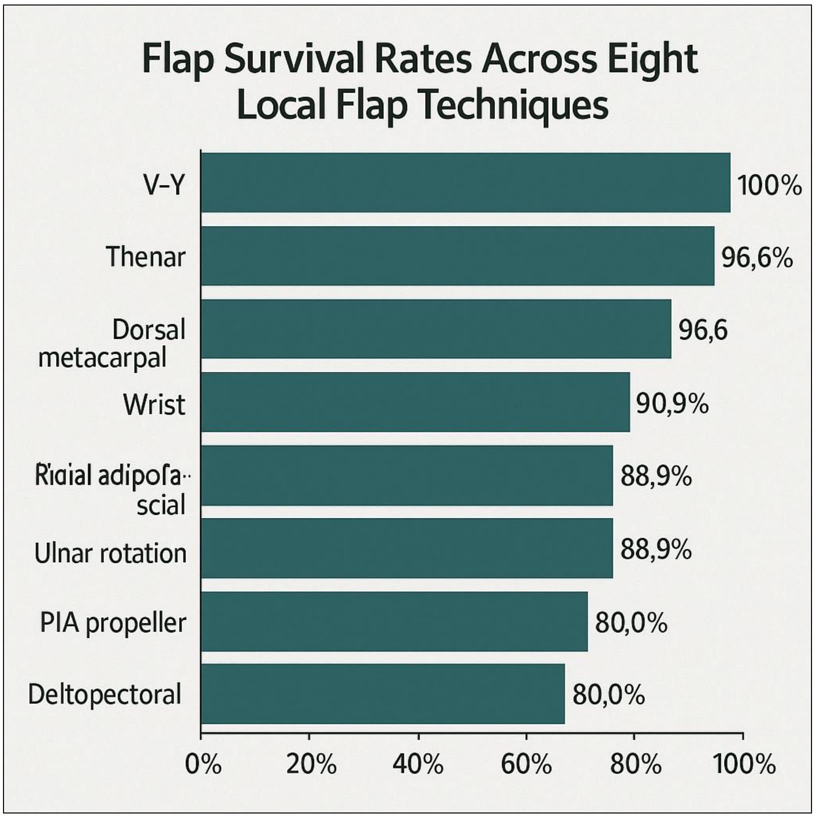

Fig 6: Kaplan-Meier curve for local flap survival over 6 months of follow-up.

The curve shows a cumulative flap survival rate of 91.1% at 6 months, with most complications (partial or total necrosis) occurring within the first postoperative week.

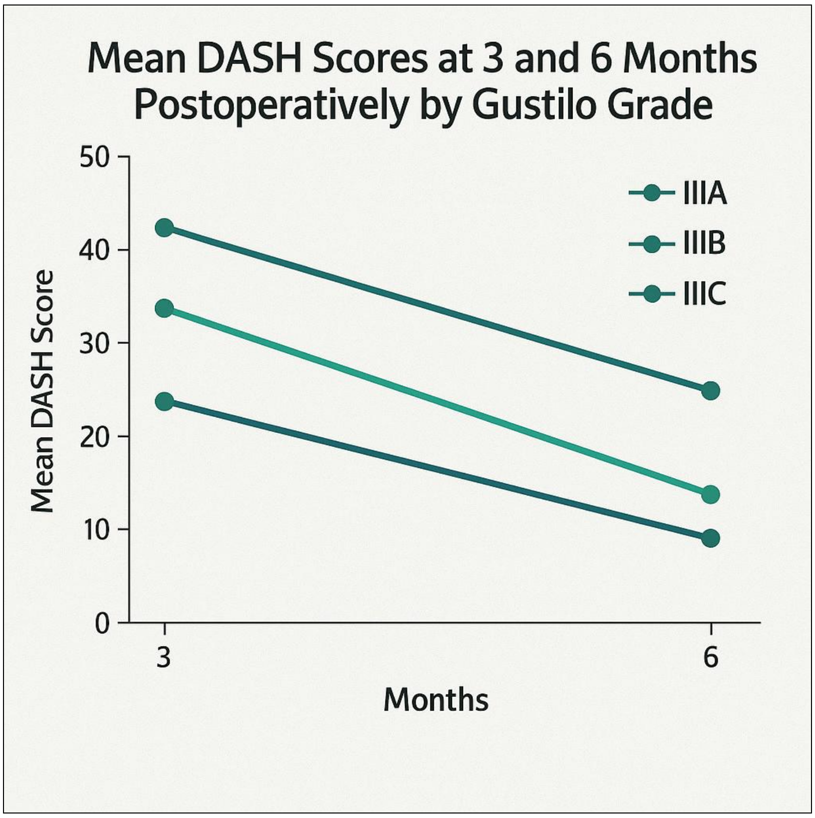

Fig 7: Improvement in functional outcomes as measured by the Arabic DASH score from 3 to 6 months, stratified by Gustilo-Anderson injury grade.

Bar graphs comparing mean DASH scores at 3 and 6 months across injury severities (IIIA, IIIB, IIIC). All groups showed statistically significant improvement (p<0.001), with best outcomes in IIIA and poorest in IIIC.

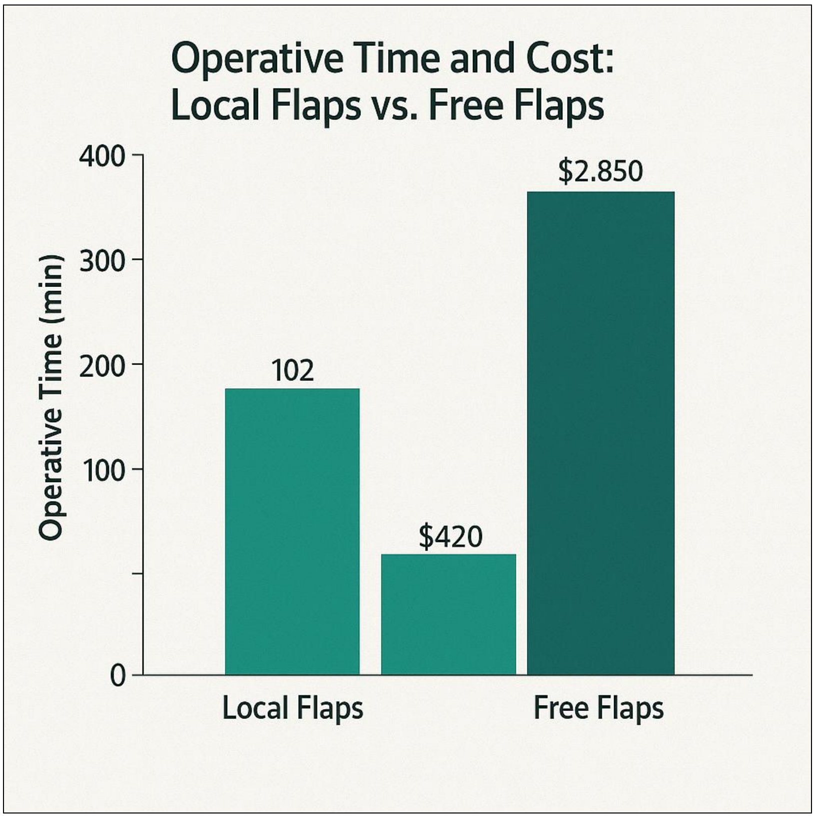

Fig 8: Comparative resource utilization: local flaps versus free flaps.

Side-by-side bar graphs illustrating key efficiency metrics: mean operative time (102 vs. 385 minutes), ICU stay (0.4 vs. 3.2 days), and per-case cost ($420 vs. $2,850 USD). Local flaps demonstrate substantial reductions in time, critical care needs, and financial burden.

Table 1: Demographic and Injury Characteristics of the Study Cohort (n = 112)

Variable	Value
Age (years), mean ±SD	27.6±9.3
Age range (years)	14 - 58
Sex, n (%)	
Male	103 (92.0%)
Female	9 (8.0%)
Occupational status, n (%)	
Civilian	89 (79.5%)
Military/Police	23 (20.5%)
Comorbidities, n (%)	
Diabetes	4 (3.6%)
Hypertension	3 (2.7%)
Smoking	31 (27.7%)
Mechanism of blast injury, n (%)	
IED	78 (69.6%)
Mortar shell	21 (18.8%)
Grenade	9 (8.0%)
Unexploded ordnance (UXO)	4 (3.6%)
Time to presentation, median (IQR)	3 days (1-7)
Time to flap coverage, median (IQR)	5 days (3-7)
Gustilo-Anderson classification, n (%)	
Type IIIA	44 (39.3%)
Type IIIB	56 (50.0%)
Type IIIC	12 (10.7%)
Associated injuries, n (%)	
Fracture	68 (60.7%)
Tendon exposure	94 (83.9%)
Bone exposure	47 (42.0%)
Nerve injury	31 (27.7%)

Table 2: Distribution of Local Flap Types by Anatomic Region (n = 112)

Anatomic Region	Flap Type	n (%)	Flap Size (cm²), mean ±SD	Flap Survival n (%)
Fingertips	V-Y advancement	8 (7.1%)	2.8±1.1	8 (100.0%)
Hand (dorsum)	Dorsal metacarpal artery flap	29 (25.9%)	17.4±5.2	28 (96.6%)
Hand (palm)	Thenar flap	6 (5.4%)	8.3±2.4	6 (100.0%)
Wrist	Posterior interosseous artery (PIA) propeller	18 (16.1%)	24.7±6.8	16 (88.9%)
Wrist	Radial artery perforator flap	7 (6.3%)	22.1±5.9	7 (100.0%)
Forearm	Radial forearm adipofascial flap	22 (19.6%)	35.2±9.1	20 (90.9%)
Forearm	Ulnar artery-based rotation flap	9 (8.0%)	38.5±10.2	8 (88.9%)
Elbow	Brachioradialis-based advancement flap	8 (7.1%)	42.0±7.5	7 (87.5%)
Upper Arm	Modified deltopectoral flap	5 (4.5%)	48.6±11.3	4 (80.0%)

Table 3: Postoperative Complications by Flap Type (n = 112)

Flap Type	n	Partial Necrosis n (%)	Infection n (%)	Complete Loss n (%)	Total Complications n (%)
Dorsal metacarpal artery	29	1 (3.4%)	1 (3.4%)	0 (0.0%)	1 (3.4%)
V-Y advancement	8	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Thenar flap	6	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
PIA propeller	18	2 (11.1%)	2 (11.1%)	0 (0.0%)	3 (16.7%)
Radial artery perforator	7	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Radial forearm adipofascial	22	2 (9.1%)	2 (9.1%)	1 (4.5%)	3 (13.6%)
Ulnar rotation	9	1 (11.1%)	1 (11.1%)	0 (0.0%)	1 (11.1%)
Brachioradialis advancement	8	1 (12.5%)	1 (12.5%)	0 (0.0%)	1 (12.5%)
Modified deltopectoral	5	1 (20.0%)	1 (20.0%)	1 (20.0%)	2 (40.0%)
Total	112	9 (8.0%)	7 (6.3%)	3 (2.7%)	11 (9.8%)

Table 4: Functional Outcomes Stratified by Gustilo-Anderson Injury Grade (n = 112)

Gustilo-Anderson Grade	n	Time to Union (weeks), mean ±SD	Good Functional Outcome n (%)	Flap Survival n (%)
IIIA	44	14.3±7.1	37 (84.1%)	43 (97.7%)
IIIB	56	21.5±10.3	34 (60.7%)	50 (89.3%)
IIIC	12	32.8±12.6	3 (25.0%)	9 (75.0%)
Total	112	19.1±9.8	76 (67.9%)	102 (91.1%)

Table 5: Comparative Resource Utilization: Local Flaps vs. Free Flaps at GAHHSS (2022 Subgroup Analysis)

Parameter	Local Flaps	Free Flaps	p value
Mean operative time (minutes)	102±28	385±62	<0.001
ICU stay (days), mean ±SD	0.4±0.6	3.2±1.8	<0.001
Blood transfusion (units)	0.8±1.1	2.3±1.9	0.002
Hospital stay (days)	8.2±2.4	14.7±4.1	<0.001
Cost per case (USD)*	$420	$2,850	<0.001
Surgeon requirement	1 plastic surgeon	2 microsurgeons + 1 assistant	—

*Estimated based on Iraqi Ministry of Health 2022 pricing guidelines.

5. Conclusion

At Ghazi Al-Hariri Hospital for Surgical Specialties, local flaps have proven to be a safe, effective, and sustainable solution for upper limb soft tissue reconstruction following blast injuries. Their integration into a structured, anatomy-based algorithm enables reproducible outcomes even in high-volume, resource-limited settings. We advocate for the dissemination of this protocol across regional trauma centers and its inclusion in national surgical training curricula for war-related reconstruction.

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How to Cite This Article
Al-Najjar FGM. Department of Plastic and Reconstructive Surgery, Ghazi al-Hariri Hospital for Surgical Specialties, Medical City, Baghdad, Iraq. International Journal of Case Reports in Surgery**.** 2025;7(2):154-165