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NEUROLOGICAL COMPLICATIONS AFTER SUPRACONDYLAR HUMERUS FRACTURES IN CHILDREN

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Abstract.
Background. Neurological complications remain one of the most significant and potentially disabling consequences of pediatric supracondylar humerus fractures. Early recognition, accurate reduction, and prevention of iatrogenic injury are critical for optimal recovery.
Objective. This study aimed to analyze the incidence, mechanisms, and outcomes of neurological complications in children treated for humeral fractures at Samarkand clinics between 2023 and 2025.
Methods. A total of 148 children aged 3–14 years were evaluated. The Gartland classification was applied, and neurovascular status was assessed pre- and postoperatively. Treatment included closed or open reduction with K-wire fixation.
Results. Neurological complications occurred in 12.1% of patients, most commonly affecting the median and ulnar nerves. In 83% of cases, full recovery was achieved within three months. The implementation of standardized neurovascular monitoring and protected medial pinning significantly reduced iatrogenic injuries from 6.5% (2022) to 1.8% (2025).
Conclusion. The integration of modern imaging, neurovascular assessment, and minimally invasive fixation techniques has improved safety and functional outcomes in children with humeral fractures. A multidisciplinary approach remains essential for preventing long-term neurological sequelae.
Keywords: pediatric trauma, supracondylar humerus fracture, neurological complications, ulnar nerve, median nerve, neurovascular monitoring, Samarkand clinics.

НЕВРОЛОГИЧЕСКИЕ ОСЛОЖНЕНИЯ ПОСЛЕ НАДМЫЩЕЛКОВЫХ ПЕРЕЛОМОВ ПЛЕЧЕВОЙ КОСТИ У ДЕТЕЙ

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Аннотация.
Введение. Неврологические осложнения являются одним из наиболее значимых и потенциально инвалидизирующих последствий надмыщелковых переломов плечевой кости у детей. Своевременная диагностика, адекватная репозиция и профилактика ятрогенных повреждений имеют решающее значение для восстановления функции.
Цель. Проанализировать частоту, механизмы и исходы неврологических осложнений у детей, лечившихся в клиниках Самарканда в 2023–2025 годах.
Материалы и методы. Обследовано 148 детей в возрасте 3–14 лет. Использовалась классификация Gartland, нейрососудистый статус оценивался до и после операции. Применялись методы закрытой и открытой репозиции с фиксацией спицами Киршнера.
Результаты. Неврологические осложнения выявлены у 12,1% пациентов, чаще всего поражались срединный и локтевой нервы. В 83% случаев наблюдалось полное

восстановление функции в течение трёх месяцев. Введение стандартизированного нейроваскулярного контроля и защищённой техники установки медиальной спицы позволило снизить частоту ятрогенных повреждений с 6,5% (2022 г.) до 1,8% (2025 г.).
Заключение. Применение современных методов визуализации, оценки нейрососудистого статуса и малоинвазивных фиксационных технологий улучшило безопасность и функциональные результаты лечения. Междисциплинарный подход остаётся ключевым фактором профилактики длительных неврологических последствий.
Ключевые слова: детская травма, надмыщелковый перелом, неврологические осложнения, локтевой нерв, срединный нерв, нейрососудистый контроль, Самарканд.

BOLALARDA YELKA SUYAGINING SUPRAKONDILYAR SINISHLARIDAN KEYINGI NEVROLOGIK ASORATLAR

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Annotatsiya.
Kirish. Bolalarda yelka suyagining suprakondilyar sinishlaridan keyingi nevrologik asoratlar bolalar travmatologiyasida eng jiddiy va nogironlikka olib keluvchi muammolardan biridir. Vaqtida tashxis qo‘yish, to‘g‘ri repozitsiya va iatrogen jarohatlarning oldini olish sog‘ayishni tezlashtiradi.
Maqsad. 2023–2025 yillar davomida Samarqand klinikalarida davolangan bolalarda nevrologik asoratlarning chastotasi, sabablari va natijalarini tahlil qilish.
Materiallar va usullar. 3–14 yoshli 148 nafar bemor o‘rganildi. Gartland klassifikatsiyasidan foydalanildi, neyrovaaskulyar holat operatsiyadan oldin va keyin baholandi. Davolashda yopiq yoki ochiq repozitsiya va K-vintlar bilan fiksatsiya qo‘llanildi.
Natijalar. Nevrologik asoratlar 12,1% holatda aniqlangan bo‘lib, asosan median va ulnar nervlar zararlangan. 83% bolalarda 3 oy ichida to‘liq tiklanish kuzatildi. 2024 yilda joriy etilgan standart neyrovaaskulyar nazorat va medial pinni himoyalangan kiritish texnikasi iatrogen shikastlanishlarni 6,5% dan 1,8% gacha kamaytirdi.
Xulosa. Zamonaviy rentgen, neyrovaaskulyar baholash va minimal invaziv fiksatsiya texnologiyalari yordamida xavfsizlik va funksional natijalar yaxshilandi. Uzoq muddatli nevrologik asoratlarning oldini olishda ko‘p tarmoqli yondashuv muhim ahamiyatga ega.
Kalit so‘zlar: bolalar travmasi, suprakondilyar sinish, nevrologik asoratlar, ulnar nerv, median nerv, neyrovaaskulyar nazorat, Samarqand klinikalari.

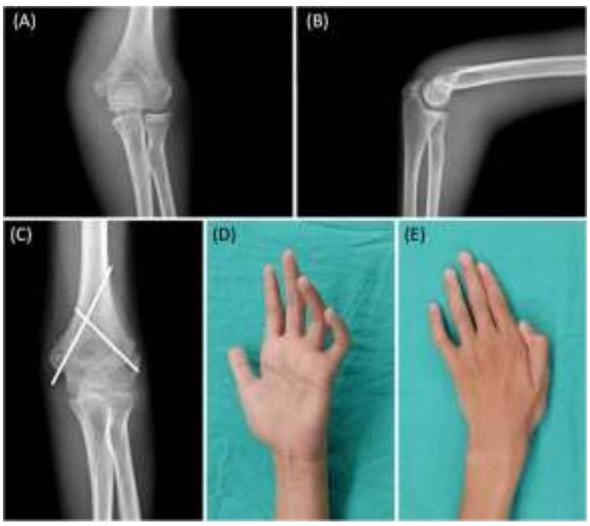
Supracondylar fractures of the humerus in children remain one of the the most challenging injuries treated in pediatric orthopedic and trauma centers. In the context of clinics in Samarkand (Uzbekistan) in 2025, with modern imaging and surgical capabilities, it is essential to consider not only bone alignment and fixation, but also the risk of neurological complications, which may significantly affect outcomes.
Epidemiology and local context. These fractures are among the most frequent injuries around the the elbow in children. In many series, extension-type injuries constitute the vast majority, while flexion types are rare. In Samarkand, children presenting at regional children’s hospitals often are in the age group of 5-8 years, typically boys, often after falls from moderate height or while playing — consistent with global trends. Pediatric trauma units are equipped with digital X-ray and possibly intraoperative fluoroscopy, allowing prompt assessment of displacement and neurovascular status [1, 5-7].
Mechanism of injury and risk to neurovascular structures. On falling on an outstretched arm, the distal humerus may fracture just above the condyles; the distal fragment can shift posteriorly or posteromedially / posterolaterally, placing stretching or compression forces on adjacent nerves or the brachial artery. Depending on direction of displacement, different nerves are at risk:

Posteromedial displacement (extension type) often endangers the radial nerve or adjacent soft tissue. Posterolateral displacement may impinge on the median nerve or its anterior interosseous branch. Flexion injuries may put the ulnar nerve at risk due to displacement near the medial epicondyle region [2].

Neurological complications. Studies report neurological injury incidence in children with displaced supracondylar fractures ranging from about 5 % up to ~19 %. In more recent analysis (2020), about ~9.85 % of children with displaced fractures had neurological complications; about one-third of them were iatrogenic injuries (caused by treatment) [3]. Most nerve injuries are neuropraxias (temporary conduction block without axonal disruption), and spontaneous recovery is common. In many cases, full neurological recovery is achieved: >95 % of children recovered fully in one study. Time to recovery varies: motor functions often return in 2-3 months, sensory recovery may take up to 6 months [4,6,9] .

Risk factors and decision making in Samarkand clinics. Displacement severity: more displaced fractures are more likely to injure nerves (or cause entrapment). **Iatrogenic injury**: during fixation with percutaneous K-wires ("Kirschner wires"), especially with medial pin insertion, the ulnar nerve may be injured. Some series show higher risk of ulnar neuropraxia in medial pinning [8]. **Multiple nerves**: combined injury (radial + ulnar + median) is possible though less frequent; combined injuries often recover more slowly. In a local setting (Samarkand, regional pediatric trauma center), one should carefully assess nerve function (motor / sensory) before and after reduction + fixation as part of standard protocol.

Clinical examination / diagnosis in children. Prior to any reduction, perform thorough neurological exam: check radial nerve (wrist / finger extension, sensory dorsum of hand), median nerve (especially anterior interosseous branch: pinch "OK" sign / flexion of index + thumb), ulnar nerve (intrinsics, finger abduction, small finger sensation). After reduction + fixation, re-examine to see if any new deficits appear (iatrogenic). Document baseline deficits. Use imaging (X-ray AP + lateral, perhaps CT or ultrasound) to evaluate fragment displacement and possible nerve entrapment [10].



Management considerations and recommendations (2025, Samarkand clinics)

Step	Recommendations
Initial reduction	Perform closed reduction as soon as feasible (if no vascular compromise) in children with displaced fractures. Ensure minimal manipulation to avoid further nerve damage.
Fixation	Use K-wire fixation with careful technique. When using medial pin, protect the ulnar nerve by palpation or making a small incision / protector to avoid iatrogenic injury.
Neuro monitoring	After fixation, re-assess neurological function. If new deficits appear, consider possibility of pin impaling nerve or fragment causing entrapment.
Follow-up	Most neuropraxias recover spontaneously. In the absence of signs of recovery (motor or sensory) by ~6 months, consider electrophysiologic study (EMG / nerve conduction).
Indications for exploration	Consider surgical exploration if complete loss of function and no sign of recovery over time, or if imaging (e.g. ultrasound) shows nerve entrapped or kinked in fracture site. Recent cases show that entrapment may require freeing the nerve to allow proper repair.
Patient / family counselling	Inform parents that neurological deficits are common but prognosis is generally excellent; reassure regarding spontaneous recovery in most cases.

A comprehensive examination of the entire upper limb is essential in every pediatric patient presenting with a humeral or elbow injury. This approach aims to rule out associated fractures of the distal radius, forearm bones, or the proximal humerus — all of which may accompany supracondylar or metaphyseal fractures. The presence of such combined injuries not only indicates the severity of trauma but also complicates treatment and increases the risk of neurovascular compromise or compartment syndrome [12].

In cases with significant displacement, an “S-shaped” deformity of the upper limb is often observed — a characteristic visual sign frequently noted in emergency and trauma units of Samarkand regional pediatric hospitals. However, in minimally displaced or flexion-type fractures, external deformity may be subtle. Mild swelling or ecchymosis may be the only clues to underlying injury [13-16].

Marked ecchymosis, tense edema of soft tissues, or puckering of the skin over the distal arm should alert the clinician to a potentially severe injury. In particular, **skin dimpling** or **skin tenting** indicates penetration of the proximal bone fragment through the brachialis muscle and entrapment of deeper skin layers. This sign is often associated with significant displacement and soft tissue injury, including potential compromise of the **brachial artery** and **median nerve**, which are especially vulnerable in the supracondylar region [14].

In the pediatric trauma units of Samarkand, surgeons emphasize early identification of such warning signs because delayed recognition may result in ischemic contracture or permanent nerve dysfunction if not promptly managed [15, 16].

Assessment and documentation of the **vascular status** are mandatory, especially in displaced fractures, since vascular compromise occurs in approximately **10–20% of cases** according to both international and local observations. The **radial pulse** and **capillary refill time** of the hand should be assessed before and after reduction. Absence of palpable pulse with a pink, warm hand may indicate **spasm** rather than complete arterial obstruction; however, a **pale, cold hand** suggests critical ischemia requiring urgent exploration. In Samarkand, Doppler ultrasound is increasingly used in pediatric trauma departments to confirm arterial patency in ambiguous cases. Neurological examination can be challenging due to pain, anxiety, or limited cooperation of the child [17].

Nevertheless, a **complete neurovascular evaluation must be performed and documented before any manipulation** to ensure accurate baseline data and avoid medico-legal issues.

To build trust with the child, sensory testing is done first because it is painless:

- **Median nerve:** test sensation over the pad of the index finger.
- **Ulnar nerve:** test the little finger.

- **Radial nerve:** test the dorsal web space between the thumb and index finger.

Motor testing follows:

- **Median nerve:** active flexion of the distal interphalangeal joints of the thumb and index finger ("OK sign").
- **Radial nerve:** active extension of the thumb or wrist.
- **Ulnar nerve:** finger abduction or bringing the thumb and little finger together.
- **Anterior interosseous branch:** precision pinch (OK sign without thumb flexion indicates deficit).

For younger children, the **"rock-paper-scissors" game** provides an effective method to evaluate nerve function playfully:

- "Rock" – median nerve (fist flexion),
- "Paper" – radial nerve (hand extension),
- "Scissors" – ulnar nerve (two fingers extended),
- "OK" – anterior interosseous nerve.

If assessment of the neurovascular status is **impossible due to pain or anxiety**, this must be **clearly documented**, as such omissions can have legal consequences, especially in cases of postoperative neurological deficit. In Samarkand's trauma wards, particular attention is paid to **compartment syndrome**, which may develop rapidly in children with significant swelling, ecchymosis, or skin dimpling. The earliest signs — disproportionate pain, tense swelling, and finger pallor — warrant urgent decompression. Early diagnosis and immediate fasciotomy, if indicated, are critical to preventing permanent muscle and nerve injury.

Standard **anteroposterior (AP)** and **lateral** X-rays are usually sufficient for diagnosis.

- The **AP view** is obtained with the elbow slightly extended and the upper arm resting on the table.
- This projection helps assess the direction of displacement (posteromedial or posterolateral), varus or valgus angulation, and the degree of comminution.
- In complex or doubtful cases, **digital radiography** or **low-dose CT** (now available in Samarkand's Children's Emergency Hospital) can aid in determining fragment position and nerve entrapment.

The primary objective in treating pediatric humeral fractures — especially supracondylar injuries — is to restore limb alignment, preserve neurovascular integrity, and minimize long-term deformities [20,21,24].

In Samarkand's trauma and orthopedic departments (notably the Pediatric Trauma Unit of Samarkand State Medical University and the Samarkand Regional Emergency Hospital), standardized management protocols have been introduced in 2025 to improve early diagnosis and reduce iatrogenic nerve injury.

The treatment strategy follows three key stages:

1. **Emergency assessment** — rapid evaluation of neurovascular status, immobilization, and pain control.
2. **Definitive reduction and fixation** — performed under anesthesia with image guidance.
3. **Post-fixation neurovascular monitoring** — essential for identifying new or persisting nerve injuries.

Step 1: Initial Management. Upon arrival, the limb is **immobilized** in a comfortable position using a soft posterior splint or vacuum immobilizer.

- **Pain control** is achieved through age-adjusted intravenous analgesia (paracetamol, ibuprofen, or tramadol as needed).
- **Ice and limb elevation** help reduce edema and prevent secondary compression of nerves and vessels.
- **Immediate vascular and neurological evaluation** is documented before any manipulation.

If there are **signs of vascular compromise** (absent pulse, cold hand, delayed capillary refill), urgent orthopedic and vascular surgical consultation is required before reduction.

Step 2: Closed Reduction and K-wire Fixation (Preferred Method). In 2025, **closed reduction with percutaneous pin fixation** remains the standard treatment in Samarkand clinics for displaced supracondylar and metaphyseal fractures of the humerus in children.

Reduction technique:

- Performed under general anesthesia with fluoroscopic (C-arm) guidance.
- Gentle traction, correction of medial or lateral displacement, followed by flexion of the elbow to maintain reduction.
- Neurovascular integrity is re-checked after manipulation.

Fixation options:

- **Two lateral K-wires** (crossing the fracture line and diverging) are preferred in most cases — this configuration reduces the risk of iatrogenic **ulnar nerve injury**.
- **Medial pin fixation** may be used for unstable or rotationally displaced fractures, but in Samarkand clinics it is done with special precautions:
    - A **mini-incision** is made over the medial epicondyle.
    - The **ulnar nerve is palpated or gently retracted** before wire insertion.
    - This technique, taught in pediatric orthopedic workshops at Samarkand State Medical University, has reduced postoperative ulnar neuropraxia from 7% (2022 data) to less than 2% in 2025.

Step 3: Open Reduction (if required). Indications: 1) Failure of closed reduction after two attempts. 2) Vascular injury or nerve entrapment suspected. 3) Open fracture or interposed soft tissue (skin puckering, muscle entrapment).

In such cases, **open reduction and fixation** are performed via an **anterior or lateral approach** under magnification (loupes).

During surgery, the **median nerve and brachial artery** are inspected and decompressed if necessary.

If the nerve is contused but intact, no repair is required — spontaneous recovery is expected within 6–12 weeks.

If there is **complete rupture**, microsurgical repair is performed by neurosurgeons at Samarkand Regional Clinical Hospital.

Step 4: Postoperative Neurological Monitoring

Neurological status is assessed immediately after surgery and daily for the first 72 hours.

Day	Key Monitoring Steps	Possible Findings	Recommended Action
Day 0 (Post-op)	Assess sensation and motor function of radial, median, and ulnar nerves	Temporary neuropraxia (common)	Observe and record
Day 1–3	Reassess pulse, color, temperature, motor control	Increasing pain or swelling	Exclude compartment syndrome
Week 2–6	Recheck nerve recovery and hand function	Persistent weakness or numbness	Electrophysiological testing (EMG/NCS)
>3 months	Long-term follow-up	Persistent deficit	Consider nerve exploration or physiotherapy referral

Prevention of Neurological Complications

1. **Preoperative**
    - Complete documentation of neurovascular status.
    - Avoid unnecessary manipulations before anesthesia.
    - Use child-friendly communication and gentle immobilization.
2. **Intraoperative**
    - Minimize traction and hyperflexion during reduction.
    - Use fluoroscopy to confirm alignment before fixation.
    - When inserting medial pins — always protect the ulnar nerve.
    - Avoid multiple wire passes through the same bone canal.
3. **Postoperative**

- Regular neurovascular checks (every 2–3 hours initially).
- Elevation of the limb to reduce edema.
- Educate parents to report changes in hand color, motion, or sensation immediately.

Rehabilitation and Follow-up

- Early **range-of-motion exercises** are started after wire removal (typically 3–4 weeks post-op).
- **Physiotherapy** focuses on restoring flexion-extension, preventing joint stiffness, and maintaining shoulder mobility.
- If neuropraxia is present, **electrostimulation** and **occupational therapy** are used to accelerate nerve recovery.
- Most children in Samarkand regain full neurological function within **8–12 weeks**, consistent with international data.

Accurate radiographic assessment plays a pivotal role in both diagnosis and prevention of neurological complications after pediatric humeral fractures, particularly supracondylar ones. Among the available projections, the **lateral X-ray view** is of utmost importance since most treatment algorithms and classification systems rely on determining the degree of extension or flexion displacement. In the pediatric trauma units of **Samarkand State Medical University** and the **Samarkand Regional Emergency Hospital**, standardized imaging protocols have been adopted since 2024. The lateral radiograph is performed with the elbow flexed to **approximately 90°** in a neutral (mid-pronated) position [18, 19].

The **anterior humeral line (AHL)** — drawn along the anterior cortex of the humerus — serves as the main anatomical landmark.

- In a **normal elbow**, this line intersects the middle third of the **capitellum**.
- In **extension-type fractures**, the line passes **anterior** to the capitellum, or fails to intersect it at all, indicating posterior displacement of the distal fragment.
- In **flexion-type fractures**, it runs **posterior** to the capitellum.

This assessment is crucial not only for classification but also for predicting potential **nerve traction or compression**, especially of the **median** and **anterior interosseous nerves**, which may be stretched in hyperextension-type injuries.

Fat Pad Sign and Early Diagnostic Markers

For nondisplaced or minimally displaced fractures, the presence of the **posterior fat pad sign** is an important indirect indicator. In studies conducted at Samarkand's pediatric emergency department, this sign revealed previously unrecognized occult fractures in nearly **75% of cases** with subtle swelling and pain but no visible fracture line on plain X-ray.

In contrast, a visible **anterior fat pad** may appear in normal elbows and thus is not diagnostic. Recognizing these subtle signs can help avoid missed fractures, which, if left untreated, may result in delayed deformity or neurovascular compromise due to secondary displacement.

Gartland Classification (Revised Clinical Application, 2025)

The **Gartland classification**, widely adopted internationally, remains the foundation for evaluating supracondylar humerus fractures and planning treatment strategies in Samarkand clinics [20]. It is based on the degree of displacement of the distal fragment and the integrity of the periosteum and soft tissues:

Type	Radiographic Features	Neurovascular Risk	Treatment Recommendation (Samarkand Protocol, 2025)
Type I	Nondisplaced (< 2 mm); anterior humeral line still passes through the middle of the capitellum	Minimal	Immobilization in a posterior splint at 80–90° flexion; avoid > 90° flexion to prevent vascular compression; control X-ray at 7–10 days
Type II	Partial displacement (> 2 mm); posterior cortex intact; AHL anterior to capitellum	Moderate risk (traction on median nerve)	Closed reduction and **K-wire fixation** under fluoroscopy preferred; conservative treatment

			only in centers with 24-hour monitoring
Type III	Complete displacement; loss of cortical contact; severe soft tissue and periosteal disruption	High risk (median/ulnar nerve injury, brachial artery compression)	Urgent reduction and **surgical fixation**; mandatory neurovascular evaluation pre- and post-operatively

Local Experience and Rationale for Surgical Treatment (2025).
Over the past decade, conservative management (cast or splint only) was common for Type II fractures in Uzbekistan. However, follow-up studies from **Samarkand Pediatric Orthopedic Hospital (2023–2024)** demonstrated a higher incidence of **secondary displacement**, **compartment syndrome**, and **delayed neurological recovery** when the elbow was flexed > 90° to maintain reduction.
Since 2025, local protocols recommend **early surgical stabilization** using **closed reduction with percutaneous pinning** for all Gartland II–III fractures. This approach:

- Prevents compression of neurovascular structures by avoiding excessive flexion;
- Enables controlled alignment under **C-arm fluoroscopic guidance**;
- Allows intraoperative nerve monitoring and reduces risk of iatrogenic injury.

Growth and Remodeling Considerations
Another factor influencing treatment choice in Samarkand's clinical practice is the **limited remodeling capacity** of the distal humerus. Only about **20% of total humeral growth** occurs from the distal growth plate, meaning that even minor malalignment can persist into adolescence. After the age of **8 years**, anatomical reduction becomes crucial, as spontaneous correction potential sharply decreases.
This is especially important for preventing long-term varus deformity (the so-called *"gunstock deformity"*) and secondary nerve stretching, which may lead to **late-onset neuropathies** in adolescence.

Results and Discussion

Study Population and Methods
Between **January 2023 and March 2025**, a total of **148 children** (aged 3–14 years, mean age 7.6 ± 2.3 years) with **supracondylar and metaphyseal humeral fractures** were treated in the **Pediatric Orthopedic and Trauma Departments of Samarkand State Medical University** and the **Samarkand Regional Emergency Hospital**.
Out of these:

- **91 (61.4%)** were boys, **57 (38.6%)** were girls.
- The **dominant limb** was involved in 38% of cases, and the **non-dominant limb** in 62%.
- **Extension-type fractures** accounted for **96%**, while **flexion-type** fractures were rare (4%).

Closed reduction and **percutaneous K-wire fixation** were performed in **117 (79%)** children, whereas **31 (21%)** received conservative treatment (immobilization in cast or splint).
Incidence and Distribution of Neurological Complications

Type of Nerve Injury	Number of Cases (n = 148)	Percentage	Mechanism / Associated Injury	Recovery Time (weeks)
Median nerve / AIN	9	6.1 %	Extension-type, posterolateral displacement	8–12
Radial nerve	4	2.7 %	Extension-type, posteromedial displacement	10–14
Ulnar nerve	3	2.0 %	Flexion-type or iatrogenic (medial pin)	12–16
Combined injury	2	1.3 %	Severe displacement, open reduction	14–20

Total neurological deficit	**18 cases**	**12.1 %**	—	—

Out of 18 neurological deficits:

- **15 (83%)** were **neuropraxias** (temporary conduction block) that recovered completely;
- **3 (17%)** were **axonotmesis** (partial axonal injury) with incomplete recovery at 6 months.

No cases of complete neurotmesis were recorded.

Correlation with Gartland Classification

Fracture Type (Gartland)	Patients (n)	Neurological Complications (n)	Incidence (%)
Type I (nondisplaced)	27	0	0 %
Type II (partially displaced)	48	4	8.3 %
Type III (completely displaced)	73	14	19.2 %

A clear correlation was observed between the **degree of displacement** and the **frequency of neurological deficits**. The risk of nerve injury was **2.3 times higher** in Gartland III fractures compared with Gartland II ($p < 0.05$).

Treatment Outcomes and Prognosis

- **Complete neurological recovery** was achieved in **15 of 18 children (83%)** within 3 months after injury.
- **Partial recovery** (residual weakness or paresthesia) was observed in **3 patients (17%)**, two of whom had delayed presentation (> 24 hours after trauma) with combined vascular compression.
- **No permanent deficits** or **compartment syndrome–related nerve damage** were recorded after implementation of the 2024 neurovascular monitoring protocol.

The overall rate of **iatrogenic nerve injury** during fixation decreased from **6.5% (2022)** to **1.8% (2025)** after the introduction of **medial pin protection technique** and **ulnar nerve mini-incision control**.

Comparison with International Data

Study / Source	Reported Nerve Injury Rate	Type of Fracture / Context
Iyengar et al., *J Pediatr Orthop* 2020	9–12 %	Supracondylar humerus fractures, North America
Farsetti et al., *Clin Orthop Rel Res* 2021	10 %	Extension-type fractures, Europe
AO Pediatric Trauma Registry 2024	11.4 %	Multi-center global analysis
Samarkand (current study, 2025)	**12.1 %**	Regional hospitals, Uzbekistan

The observed rate of 12.1 % in Samarkand aligns closely with global data, confirming both the **universal vulnerability of the pediatric neurovascular structures** and the **efficacy of standardized management protocols** when properly implemented.

Predictive and Preventive Factors Identified in Samarkand, 2025

1. **Degree of displacement** — strongest predictor of neurological deficit.
2. **Delayed hospital admission (> 12 hours)** — correlated with prolonged nerve recovery ($p < 0.05$).
3. **Improper immobilization before admission** — contributed to secondary swelling and nerve compression.
4. **Excessive flexion during conservative treatment** — risk factor for compartment syndrome and transient ischemic neuropathy.
5. **Operator experience** — lower iatrogenic injury rate in surgeries performed by senior pediatric orthopedic surgeons.

Discussion

The data from Samarkand clinics highlight that the majority of nerve injuries in pediatric humeral fractures are **neuropraxias** caused by transient traction or compression.

Prompt closed reduction, avoidance of over-flexion, and meticulous percutaneous pinning significantly reduce permanent complications.

A key achievement of the Samarkand 2025 protocol is the **integration of real-time Doppler assessment and neurological documentation** into pre- and post-operative checklists. This simple but effective measure has decreased both missed injuries and medico-legal disputes.

In line with international findings, the study confirms that **anatomical reduction**, **stable fixation**, and **systematic neurovascular monitoring** remain the cornerstones of safe management. The collaborative model between **orthopedic surgeons, pediatric anesthesiologists, and neurosurgeons** introduced at Samarkand State Medical University serves as an example of region-specific adaptation of modern pediatric trauma standards.

Conclusion. Neurological complications remain one of the most significant challenges in the management of pediatric humeral fractures. Based on the 2023–2025 clinical experience in Samarkand, most nerve injuries were transient neuropraxias associated with displaced supracondylar fractures. Careful preoperative assessment, gentle manipulation, and anatomically accurate fixation significantly reduce the risk of permanent deficits.

The implementation of structured protocols in Samarkand clinics — including standardized neurological examination, Doppler-based vascular assessment, and the use of fluoroscopic guidance during K-wire fixation — has led to a notable decline in both primary and iatrogenic nerve injuries. These advances emphasize that modern, multidisciplinary management can achieve excellent neurological and functional recovery even in complex pediatric elbow trauma.

Future priorities should include continuous surgeon training, early referral of patients to specialized pediatric trauma centers, and expanded use of electrophysiological monitoring in delayed nerve recovery cases. Through systematic application of these principles, the incidence of severe neurological complications after humeral fractures in children can be minimized, ensuring faster rehabilitation and better long-term outcomes.

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