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# Duplex ultrasound for assessing vascular impairment after supracondylar humerus fractures

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**Abstract**

**Background:** Supracondylar humerus fractures (SHF) are the second most common fracture in children and the most common fracture in children under seven years. Subtle neurovascular lesions in displaced SHF may be underdiagnosed clinically, but their sequelae can mean life-long symptoms. Here we show that color-coded duplex ultrasound (DUS) could help to identify these patients.

**Methods:** We reviewed records of 229 children who had recovered from SHF. Ninety patients were available for detailed questionnaires, in-depth neurovascular examinations, and DUS.

**Results:** In 90 examined patients, only two had been known to have suffered from vascular complications before our study. Only one still complained spontaneously about perfusion-induced symptoms. Qualitative changes in blood flow in duplex-sonography were detectable in both. Another two patients showed similar changes in blood flow at the fracture site. Both reported load-induced pain and paresthesia on detailed inquisition when no vascular impairments had been known before. Thus, duplex-sonography identified two patients with vascular affections that had not been noticed before in routine clinical examinations.

**Conclusion:** DUS can be a sensitive tool in diagnosing vascular impairments in patients with SHF. It could reduce diagnostic insecurity, especially in anesthetized or otherwise hard to examine children, and thus help avoid the therapeutic delay that otherwise might foster life-long sequelae for the patients. More studies are needed to establish age-adjusted reference values for duplex-sonography of children's arms. Level of Evidence: Level III, Study of nonconsecutive patients (without consistently applied reference).

**Abbreviations:** AO = Arbeitsgemeinschaft Osteosynthese, DUS = color-coded duplex ultrasound, ED = end-diastolic flow, SHF = supracondylar humerus fractures, SS = systolic peak flow.

**Keywords:** duplex ultrasound, supracondylar humerus fracture (SHF), vascular injuries

## 1. Background

Supracondylar humerus fractures (SHF) represent up to 17.9% of all fractures in children younger than 16. This makes them the second most common fracture in children and the most common fracture in children under seven.[1] Vascular impairment is a known complication occurring in up to 11.9% of displaced fractures based on clinical examination[2] and up to 73% when more subtle vascular changes are diagnosed with the help of color-coded duplex ultrasound (DUS).[3] Due to the proximity of nerves and vessels to the fracture site, nerve injuries can frequently accompany vascular compromise.[4]

Many authors have dealt with vascular compromise management in SHF.[5,6] Most children are doing fine according to routine clinical examination after recovery from SHF. Apparently, children tolerate even the brachial artery's ligation since children who received Scribner shunts in the past did not complain many sequelae.[7] Many authors have also dealt with the phenomenon of the "pink pulseless hand" after SHF, some

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define it as perfused hand without a palpable pulse when others use a Doppler to search for a radial pulse when in doubt. A recent meta-analysis has concluded that these patients need close monitoring.[5] However, the long-term clinical importance of subtle vascular impairments may be underestimated, and more detailed examinations and inquiries could elicit more subtle symptoms. Furthermore, the "pink pulseless hand" is not always consistently and unequivocally defined. Thus it remains uncertain what "watchful waiting" can mean to both clinician and patient, and color-coded duplex ultrasound could be beneficial to assess the nature of vascular compromise and inform treatment decisions.[8]

The diagnosis of vascular impairment in SHF can be challenging. Young age, stress, different developmental levels, high body mass index, casts or dressings, sedation, or anesthesia with concomitant low systemic blood pressure can hamper the neurovascular examination. Given that sonography becomes more and more decisive in diagnosing and monitoring fractures,[9,10] it is the purpose of this report to demonstrate the potential of DUS to identify patients with vascular compromise after SHF that is yet only reported in selected studies[3,11,12] but still far from clinical routine.

## 2. Methods

We screened our records for patients 0 to 15 years of age who had suffered SHF from January 2005 to December 2008 and identified 229 patients with the International Statistical Classification of Diseases and Related Health Problems diagnosis S42.4. For all fractures, we collected baseline data, including age, sex, fracture classification, and management. Ninety patients completed a follow-up appointment, including a detailed clinical history, clinical examination, and DUS. They all completed a 10-item questionnaire (supplementary file, http://links.lww.com/MD/G698), asking for cold-intolerance, differing temperatures in the hands, pain on exercising, leisure activities, pain, dysesthesia, change of handedness, hand pain while writing, other sequelae of the fracture, and accompanying injuries. We then subjected all patients to a detailed physical examination including peripheral pulse frequencies, pulse intensity, and pulse quality, capillary refill, arm length, elbow axis, range of movement, the temperature of the skin, and sensibility to light touch, all of the above in comparison to the uninjured arm. Patients then received a DUS scan (Acuson S2000, Siemens Healthcare, Linear 14L5) of both arms' brachial (directly proximal to the cubital fossa), ulnar, and radial arteries (both directly proximal to the wrist). Scans were conducted by KS who was trained in DUS. The following parameters were calculated from these scans and recorded: pulsatility- and resistance index, standardized peak and mean flow, systolic peak and end-diastolic flow (SS and ED) with SS/ED quotient, and vessel diameter. There was no blinding of the investigator regarding history, clinical examination, questionnaires, or DUS. This study was covered by the Ethical Board of TU-Dresden under approval EK 433102016. All parents gave informed consent.

## 3. Results

In the analyzed 4-year period, we treated 229 patients from 0 to 17 years of age (average 6 years) with SHF. 51.5% boys and 48.5% girls. Ninety patients (39.3%) showed up for our long-term follow-up examination 5 to 45 months after their trauma (mean 30 months). Among these were 45 girls and 45 boys. According to the Basel classification, forty-two patients (46.7%) have had a Type I (no dislocation, Arbeitsgemeinschaft Osteosynthese (AO) 13-M/3.1 I) or II fracture (posterior displacement of the capitulum only, AO 13-M/3.1 II).[13] They were treated conservatively. Forty-eight patients (53.3%) had Basel III (rotated, AO 13-M/3.1 III) and IV fractures (dislocation in all three planes, AO 13-M/3.1 IV) and were surgically treated accordingly. Only two patients had been known before to have suffered vascular impairment: one patient got an interposition graft from the greater saphenous vein after the second revision of the brachial artery. In this patient, neither clinical- nor perfusion-related symptoms on the questionnaire were reported. This patient's DUS was normal. The second previously known patient became apparent with a missing radial pulse after reduction. Magnetic resonance angiography showed a brachial interruption but satisfying collateralization. Clinically the patient had a warm hand with normal capillary refill time. During follow-up, this patient showed a side difference of hand temperature and load-induced pain while writing. This patient showed a conspicuous DUS (Fig. 1).

Two additional patients showed similar sonographic changes with raised resistance index and overall reduced flow (Fig. 1).

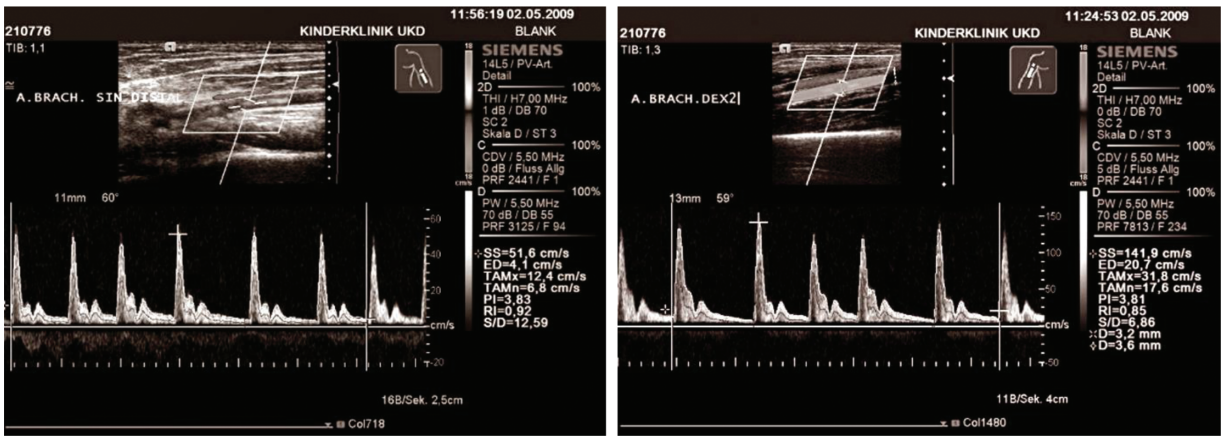


**Figure 1.** Conspicuous DUS on the left with systolic peak flow (SS), end-diastolic flow (ED), mean flow (TAMn) decreased, and resistance index (RI) raised.

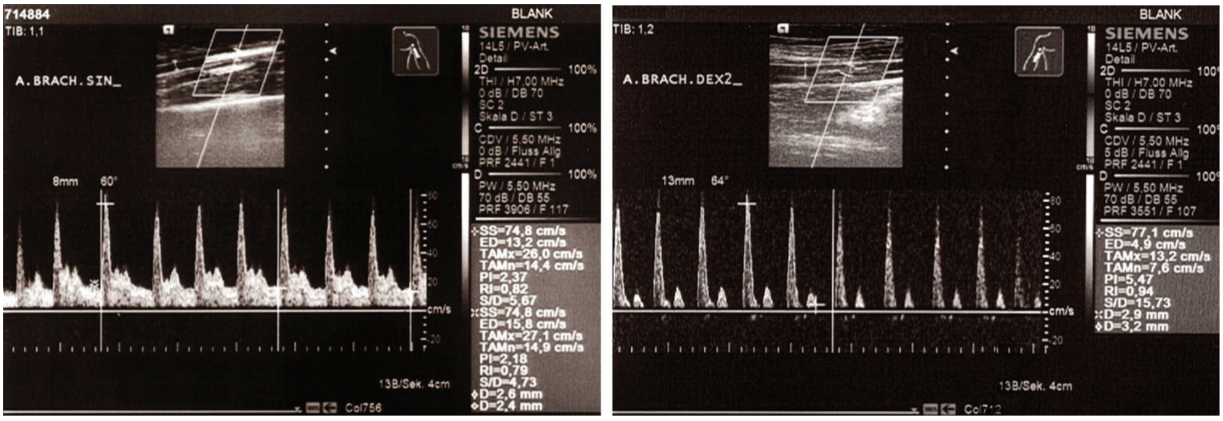


**Figure 2.** Pathological tri-phasic DUS on the right with negative flow, end-diastolic flow (ED), and mean flow (TAMn) decreased, while systolic peak flow (SS) and resistance index (RI) are raised.

One of them reported claudication symptoms while playing volleyball. However, the capillary refill was normal in all patients. Intriguingly, in the questionnaire and clinical follow-up, exclusively these three patients presented with load-induced claudication.

In four patients, DUS of the previously fractured arm revealed clear pathologies, that is, a tri-phasic picture with negative flow, ED, and mean flow decreased, while SS and resistance index were raised (Fig. 2). Two of these four had not been known to have any vascular deficit beforehand. These four patients all had Basel III or IV fractures. No pathological changes on DUS were found in conservatively treated patients with type I or II fractures. No patient had complete occlusion of the brachial artery (Supplementary file 2, http://links.lww.com/MD/G699.).

## 4. Discussion

Our study shows that DUS can be a sensitive tool in diagnosing vascular impairment in patients with supracondylar fractures: we were able to detect changes so subtle that they had been missed in the routine clinical examinations before. All affected patients showed noticeable changes in their DUS. Furthermore, consistent with the concept of internal controls, no type I or type II fractures showed pathologies on DUS.

Even experienced clinicians can easily miss mild neurovascular symptoms in children when delayed treatment negatively affects the prognosis.[14,15] We acknowledge that the brachial artery's compromise might not be of severe clinical consequence in most children,[16] as the brachial artery has been sacrificed for Scribner shunts in children without signs of ischemia or growth anomalies.[7] However, most of these patients experience mechanical or cold stress intolerance and claudication to some extent.[7] Initially missed signs and symptoms become more evident as children grow. Eventually, these symptoms become disturbing at some point, and similar to peripheral nerve injuries, long-term quality of life impairment might be the consequence.[17]

Moreover, the median nerve entrapment in SHF is often associated with vascular entrapment, leading to life-long symptoms. In SHF, the challenging clinical problem of subtle but life-long neurovascular symptoms is not restricted to the rare entity of the pink pulseless hand but a phenomenon possibly more frequent when looked for more closely. The primary goal of modern medicine must be the full recovery of our patients. Thus, the diagnosis of any vascular compromise should be of interest to the concerned clinician.

Meticulous clinical examinations and thorough history taking can identify lasting pathologies in the follow-up of SHF patients. Claudication symptoms when working or playing overhead are a rather specific and sensitive sign of vascular impairment. However, in an acute situation or when diagnosis is complicated by other factors, DUS can help diagnose arterial compromise in SHF. Since DUS as a point of care diagnostic is relatively easy to learn and applicable in emergency rooms, operating theatres, and outpatient clinics, it could also help avoid invasive diagnostics, radiation, additional general anesthesia, and delayed therapy. DUS could diminish diagnostic insecurity, and it might also help achieve our goal to obtain definite restitution with one initial operation. Because of recent advances in the sonographic diagnosis and monitoring of fractures, evaluating neighboring vessels in danger could become routine clinical practice. In the future, distinguishing internal reasons for blood flow pathologies such as thrombosis or vasospasms from external causes such as entrapments or compression might help target clinical management accordingly. We now routinely include DUS of children with SHF as soon as there are any doubts about their neurovascular status, whether in the emergency room, operating theatre, ward, or outpatient clinic. However, the present study is very limited since only four patients showed clearly pathological, that is, tri-phasic scans. Due to its retrospective nature the exact clinical signs at the time of the injury were not determined and recorded in a standardized way. Most patients did not have any external gold-standard reference tests such as MRI-angiography. Prospective studies are needed to evaluate the role of duplex in the acute setting. Future studies need to record even subtle symptoms including functional tests to detect perfusion-related problems.[18] To further evaluate what we called "conspicuous scans" and to insert DUS into routine diagnostics even for inexperienced users, we need large studies to establish reference values in children's arms' duplex sonography.

## Author contributions

**Conceptualization:** Guido Fitze, Katja Storch.
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**Resources:** Guido Fitze.
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**Validation:** Guido Fitze, Katja Storch.
**Visualization:** Jurek Schultz, Katja Storch.
**Writing – original draft:** Jurek Schultz, Katja Storch.
**Writing – review & editing:** Guido Fitze, Jurek Schultz, Katja Storch.

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