Spike the PCHA! Overuse injury of the Posterior Circumflex Humeral Artery in elite volleyball
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CHAPTER 6

B-mode ultrasound assessment of the Posterior Circumflex Humeral Artery - The SPI-US protocol: a technical procedure in 4-steps

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ABSTRACT

Elite overhead athletes are at risk of vascular injury due to repetitive abduction and external rotation of the dominant arm. The posterior circumflex humeral artery (PCHA) is prone to degeneration, aneurysm formation and thrombosis in elite volleyball players and baseball pitchers. PCHA related thromboembolic complications prevalence is unknown in this population. However, the prevalence of symptoms associated with digital ischemia is 31% in elite volleyball players. A standardized non-invasive imaging tool will aid in early detection of PCHA pathology, prevention of thromboembolic complications, and measurement reproducibility. A standardized vascular US protocol for assessment of the proximal PCHA (SPI-US protocol) is presented.
INTRODUCTION

Elite volleyball players frequently suffer from cold, discoloured, and painful fingers in the dominant hand which might be the result of emboli derived from the posterior circumflex humeral artery (PCHA) in the ipsilateral shoulder. The PCHA is a side branch of the third part of the axillary artery and is prone to degeneration in elite overhead athletes, such as volleyball players and baseball pitchers, as a result of vascular injury due to repetitive abduction and external rotation of the arm. This repetitive injury of the proximal PCHA can lead to degeneration, aneurysm formation, thrombosis, and distal embolization. The prevalence of elite overhead athletes with PCHA related thromboembolic complications is still unknown. However, the prevalence of digital ischemic symptoms is up to 31% in elite volleyball players. A late diagnosis can disable the overhead athlete and threaten the athletes career.

Correct and timely recognition of signs and symptoms of embolization are key in diagnosis. An attractive imaging modality is vascular ultrasound (US), that is readily available, applicable on-site, inexpensive, and patient friendly. In general US is the first-line imaging modality for aneurysm assessment. It enables non-invasive and patient friendly measurement of vessel diameters and detection of intravascular thrombus. Early detection of PCHA degeneration, aneurysm formation and intravascular thrombus can potentially prevent thromboembolic complications and irreversible tissue damage. Currently there is no standardized vascular US PCHA protocol available. A standardized US PCHA protocol is important because worldwide standardization and implementation will aid in targeted and accurate PCHA imaging.

The PCHA is a relatively small branch arising from the axillary artery. The axillary artery (AA) is a continuation of subclavian artery distal to the first rib and gives rise to six branches, according to most descriptions. The superior thoracic artery arises from the first part of AA. The thoracoacromial artery (TAA) and lateral thoracic artery (LTA) arise from the second part. Three branches arise from the third part; the subscapular artery (SAA), anterior circumflex humeral artery (ACHA), and PCHA (Figure 1). The PCHA frequently is the last branch arising from the AA. However, the deep brachial artery (DBA) arising from the proximal brachial artery frequently has an aberrant origin, and may arise from the dorsal AA, nearby and closely resembling the PCHA. The PCHA is prone to degeneration in overhead athletes where the DBA has not been reported to be at risk in overhead athletes in the medical literature. Therefore it is important to discriminate the PCHA from the DBA. The prevalence of PCHA origin variations is up to 33-42%. Common PCHA anatomical variants include a common trunk of SSA and PCHA (12-34%) (Figure 2), or a common trunk of the PCHA and DBA (8%) (Figure 3).
The proximal PCHA is characterized by its dorsal origin, slight obtuse angle, and curved course running along the dorsal surgical neck of the humeral bone, deflecting from the AA. The proximal DBA is also characterized by a dorsal origin, but with a sharp angle, and a straight course running almost parallel to the AA towards the triceps brachii muscle. This anatomical knowledge is important for correct PCHA identification.

Aneurysm can be defined as a segmental vessel dilatation of more than 50% compared to the closest normal appearing vessel segment proximal or distal to the aneurysmatic segment. An example of an aneurysmatic PCHA in an elite volleyball player is shown in Figure 4.

A known limitation of US is that it is observer dependent which may limit the diagnostic accuracy of this imaging modality. Both cross-sectional and longitudinal views are important to identify vessels, their course and to localize abnormalities. Furthermore, the reproducibility of vascular diameter measurements can be improved by using both cross-sectional and longitudinal views for the assessment of vascular diameters. The cross-sectional diameter measurement should be performed perpendicular to the vessel centerline whereas in the longitudinal view the diameter measurement should be performed along the centerline. Standardization of vascular US protocols is important to improve inter- and intra-observer reproducibility. However, a standardized PCHA US protocol is currently not available to enable accurate diagnosis of PCHA pathology. Therefore, we present a 4-step standardized vascular US protocol for assessment of the proximal PCHA: the SPI-US protocol (Shoulder PCHA pathology and digital ischemia – Ultrasound protocol).
Figure 1 Classic PCHA origin from the axillary artery
I, first part of axillary artery; II, second part of axillary artery; III, third part of axillary artery; B, brachial artery; STA, superior thoracic artery; TAA, thoracoacromial artery; LTA, lateral thoracic artery; ACHA, anterior circumflex humeral artery; SSA, subscapular artery; PCHA, posterior circumflex humeral artery; DBA, deep brachial artery

Figure 2 Common trunk of the PCHA and SSA
I, first part of axillary artery; II, second part of axillary artery; III, third part of axillary artery; B, brachial artery; STA, superior thoracic artery; TAA, thoracoacromial artery; LTA, lateral thoracic artery; ACHA, anterior circumflex humeral artery; SSA, subscapular artery; PCHA, posterior circumflex humeral artery; DBA, deep brachial artery
Figure 3 Common trunk of the PCHA and DBA
I, first part of axillary artery; II, second part of axillary artery; III, third part of axillary artery; B, brachial artery; STA, superior thoracic artery; TAA, thoracoacromial artery; LTA, lateral thoracic artery; ACHA, anterior circumflex humeral artery; SSA, subscapular artery; PCHA, posterior circumflex humeral artery; DBA, deep brachial artery

Figure 4 Longitudinal B-mode ultrasound image of the aneurysmatic proximal PCHA in a professional volleyball player. AA, axillary artery; PCHA, posterior circumflex humeral artery
ULTRASOUND PROTOCOL

Step 1. The patient is seated next to the operator with the target arm in 60° abduction with the hand resting on the iliac crest (Figure 5). A high frequency broadband linear array transducer is positioned sagittal oblique in the axillary pit, directed towards the gleno-humeral joint. The axillary artery (AA) and the axillary vein (AV) are identified by a cross-sectional sweep and longitudinal view. Both views are important to identify the course and calibre of the vessels and localization of abnormalities. In general, the AV is larger than the AA and the AV is compressible, whereas the AA is not. An important landmark is the large calibre TAA, arising from the dorsal side of the AA (Figure 6).

Step 2. A cross-sectional sweep is performed from the axillary pit down to the origin of the brachial artery for general anatomical evaluation, localization of side branches and for specific assessment of the PCHA and DBA.

Step 3. The PCHA and DBA are identified. The PCHA origin is located proximal to the DBA origin. The proximal PCHA is characterized by its dorsal origin and curved course running along the dorsal surgical neck of the humeral bone, deflecting from the AA (Figures 7 and 8). The proximal DBA is also characterized by a dorsal origin and has a straight course running almost parallel to the AA towards the Triceps Brachii muscle. The DBA is the last dorsal branch of the AA in the axillary pit (Figure 9).

Step 4. The PCHA and DBA diameters are measured at approximately 1 cm distance from the origin. In the event of PCHA dilatation, the maximum diameter of the PCHA is measured. In addition the diameter of the closest normal appearing PCHA vessel segment proximal, or otherwise distal, to the dilated vessel segment is measured. Additionally, the presence of intravascular thrombus and/or vessel occlusion is identified and recorded. Waveform characteristics are obtained to visualize a triphasic or blunted signal. A blunted signal is correlated with a more distal occlusion.
Figure 5 Participants position during the examination

Figure 6 Cross-sectional view at the proximal axillary pit
AA, axillary artery; TAA, thoracoacromial artery
Figure 7 Cross-sectional view of the PCHA; 1. At PCHA origin; 2. Half way to surgical neck of the humerus; 3. Along surgical neck of the humerus
AA, axillary artery; PCHA, posterior circumflex humeral artery; HH, humeral head
**Figure 8** Longitudinal view of the PCHA
AA, axillary artery; PCHA, posterior circumflex humeral artery

**Figure 9** A. Cross-sectional view of the DBA; B. Longitudinal view of the DBA
AA, axillary artery; AV, axillary vein; DBA, deep brachial artery; HH, humeral head
IMPLEMENTATION

Volleyball is among the most widely played sports in the world and is played by around 260 million people regularly. Elite volleyball players worldwide are potentially at risk of PCHA aneurysm and thrombosis with distal embolization. Diagnosis is established based on history-taking, physical examination and diagnostic imaging, both non-invasive and invasive. Non-invasive testing, like digital photoplethysmography and vascular ultrasound, are used in the work-up towards invasive testing, i.e. digital subtraction angiography (DSA), the standard of reference or less invasive computed tomographic angiography (CTA). Both are associated with ionizing radiation and the use of contrast media. However these modalities are currently required for diagnosis and treatment planning. Athletes present themselves late in disease with symptoms of digital ischemia in daily life. Symptoms include coldness, discoloration, pain and paresthesia. These symptoms may cause severe discomfort, reduced daily quality of life, and may ultimately lead to necrosis and finger loss when trivialized.

In an early stage of disease, the aneurysm is occult as long as the player is free of symptoms. Symptoms might only manifest after overhead movements in volleyball, when emboli are squeezed out of the aneurysmatic and thrombosed PCHA into the axillary artery and embolize into the digital circulation. This can lead to transient local coldness and discoloration during or directly after volleyball. A screening questionnaire can be used to triage these athletes who experience vague symptoms during volleyball, possibly related to distal embolization. These athletes might benefit from non-invasive screening diagnostic imaging in an early stage to objectify local PCHA pathology. A convenient imaging modality is vascular ultrasound (US), which is readily available, inexpensive, patient friendly and enables on-site application.

Vascular ultrasound has been reported previously to visualize and measure blood flow in the distal PCHA in healthy volunteers through a posterolateral approach on the upper arm. However, the majority of PCHA pathology in volleyball players has been reported in the proximal part of the PCHA, near the take-off from the axillary artery. This is consistent with the location of pathology seen in volleyball players who were diagnosed and treated in our academic hospital.

The presented standardized vascular (SPI-US) protocol is quick and easy and enables on-site application which can aid in early detection of PCHA pathology. Furthermore, this protocol can be used in a clinical setting in the diagnostic work-up towards diagnosis and treatment planning. Standardization of US PCHA imaging will contribute to the reproducibility of the acquired measurements, intercollegial exchange of reference values, and more knowledge on this overhead-sport-specific injury. The protocol instructions and corresponding images provide clear guidance for identification and
assessment of the PCHA. International dissemination of this protocol should make it possible to identify PCHA injury at an early stage. A first step to do so has been taken during a large international beach volleyball tournament in the summer of 2014.

In conclusion, a standardized 5 to 10 minute vascular US (SPI-US) protocol is presented for PCHA assessment in order to detect aneurysm related embolization. The results of a subsequent study to determine the reproducibility and accuracy of the presented protocol are expected.