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Targeting arteriovenous malformations without an invasive head ring - A new software prototype

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Introduction
Arteriovenous malformations (AVMs) are abnormal, snarled tangles of blood vessels that cause multiple irregular connections between the arteries and veins. In order to correctly locate an AVM, typically, a digital subtraction angiography (DSA) is carried out. To use the DSA for target definition an accurate image registration between CT and DSA is required. Carrying out a non-invasive, frameless procedure, i.e. having no invasive head frame in place that serves as a fixed coordinate system, registration of the 2D-DSA images with the CT is critical. A new software prototype (called prototype below) is enabling this frameless procedure. The aim of this work was to evaluate the prototype in terms of targeting accuracy and reliability based on phantom measurements as well as with the aid of patient data. In addition, the user's ability to recognize mismatches on the present image modalities and quality was assessed.

Materials and Methods
Targeting accuracy was measured with a simple cubic, as well as with a more realistic anthropomorphic head phantom. Clearly defined academic targets within the two phantoms were contoured on the CT. The center of mass (COM) coordinates of these reference structures were compared with the COM coordinates of the structures generated within the prototype, based on the 2D-DSA images. A similar approach was used with patient data, where the clinically contoured target served as the reference structure.
In order to check if the user is able to recognize registration errors on blended digitally reconstructed radiographs (DRR) and 2D-DSA projection images, a set of different registration errors (translations and rotations) was introduced to the correctly registered CT and 2D-DSA image data sets of three different patients. Each of six different users rated the whole set of registrations within the prototype.

Results
The target accuracy of the prototype was found to be below 0.04 cm for the simple cubic phantom and below 0.05 cm for the anthropomorphic head phantom. The mean target accuracy for the 15 patient cases was found to be below 0.3 cm.
Almost all introduced registration errors above 1° or 0.1 cm were detected by the six users and were rated as not acceptable. Nevertheless, in order to quantify and categorize the possibility to detect mismatches (sensitivity and specificity) in the registration process more data needs to be evaluated.

Conclusions
Our study shows, that the prototype is a useful tool that has the potential to fill the gap towards a frameless procedure when treating AVMs with the aid of 2D-DSA images in radiosurgery. The target accuracy of the prototype is similar to other systems, which are already well established in clinical routine.

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