Assessment of a Cloud-based Artificial Intelligence-driven Aortic Volume Assessment Software Device in Clinical Practice

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Background

Sac regression after endovascular aneurysm repair (EVAR) has been surveilled with serial Computed Tomography (CT) scans in which subjective maximum diameter measurements have been used to assess sac regression, a strong marker of EVAR success.[1,2] More recently, with the advent of artificial intelligence (AI) driven software, aortic volumetric calculation after EVAR has emerged as a potentially more accurate and sensitive tool, although its results require further validation.[3,4]

Aim

Assess the utility, as measured by accuracy, of an integrated, cloud-based platform that uses AI-driven software device to automatically measure aortic volumes to compare sac size both pre-and postoperatively to quantify EVAR success.

Methods

Automatic Volume Assessment (AVA) is a feature of Cydar Maps (Cydar Medical, UK), an FDA-cleared software device that aids in planning, intraoperative guidance, and postoperative assessment of endovascular patients. Figure 1 shows an example patient aortic volume change from the preoperative scan to available follow-up CT scans. Figure 2 shows renderings from a series of CT scans after successful aneurysm repair. At the center of the AVA software is an image segmentation model which uses a neural network 3D U-Net deep learning architecture to segment entire aortic anatomy (Figure 3).[5] The algorithm was trained using >2000 CT scans from diverse patient populations. The model also sections the aorta into regions based on branching vessels. The volume reported comes from the combination of three of these regions (infrarenal aorta plus both common iliac arteries) as shown by the orange regions in Figures 1 and 2.

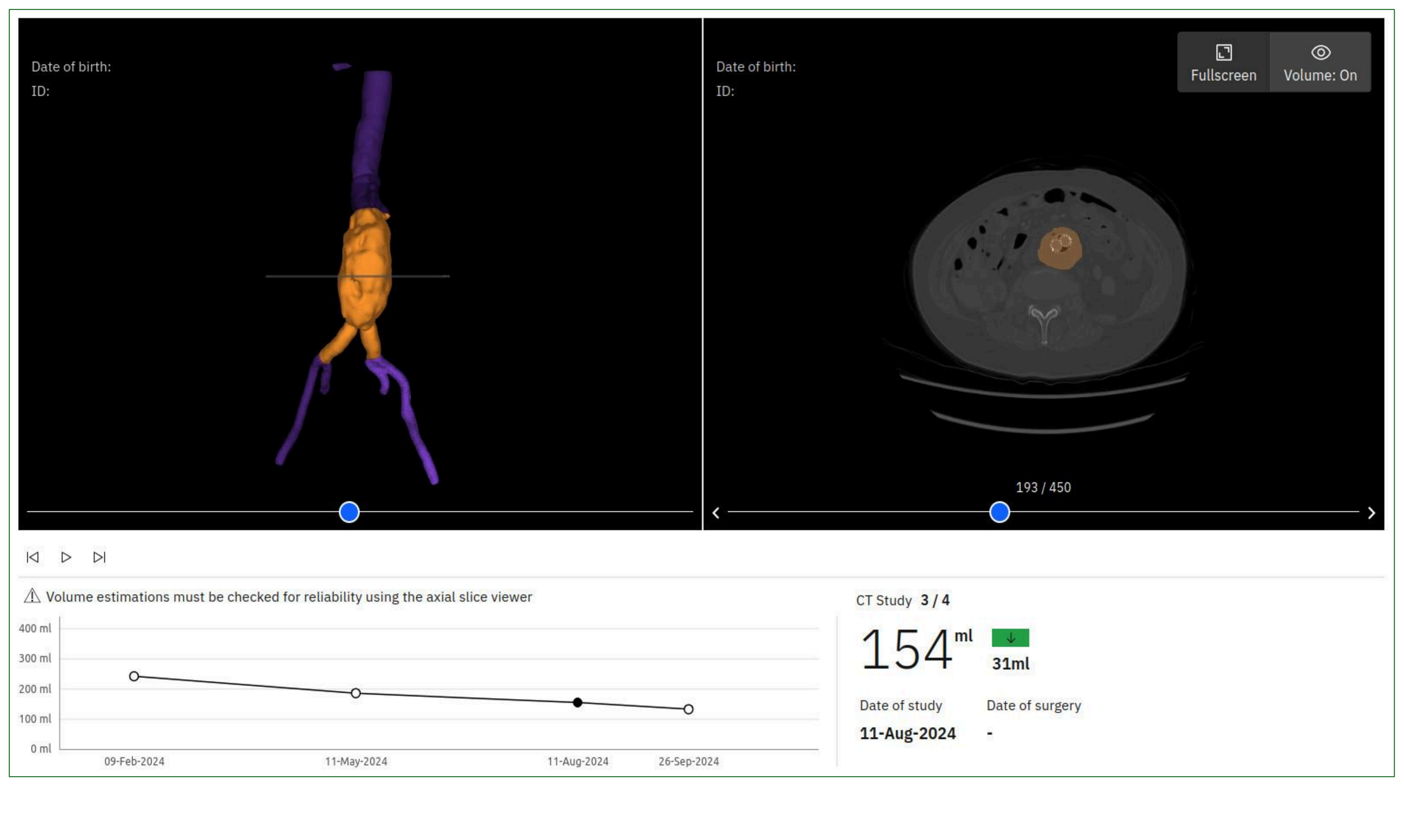

Figure 1.Automatic Volume Assessment (AVA) interface in Cydar Maps. The graph (bottom) shows the change in aortic volume over time, for the preoperative CT scan and three follow-up scans. The segmented volume can be viewed as a 3D rendering or as an overlay on the axial CT slices. The AVA volume (infra-real aorta plus common iliac arteries) is shown in orange.

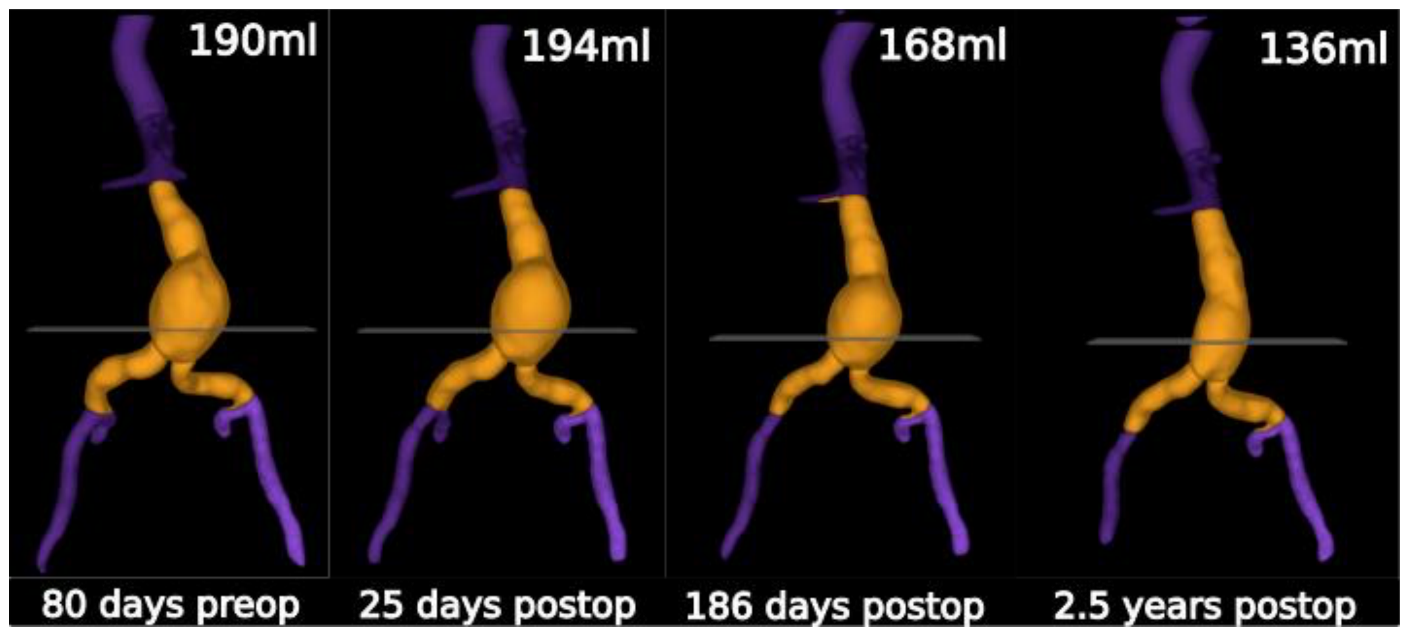

Figure 2. Series of surface renderings from preoperative CT scan (far left) and three follow up scans. Segmentations show decrease in aortic volume after successful aneurysm repair.

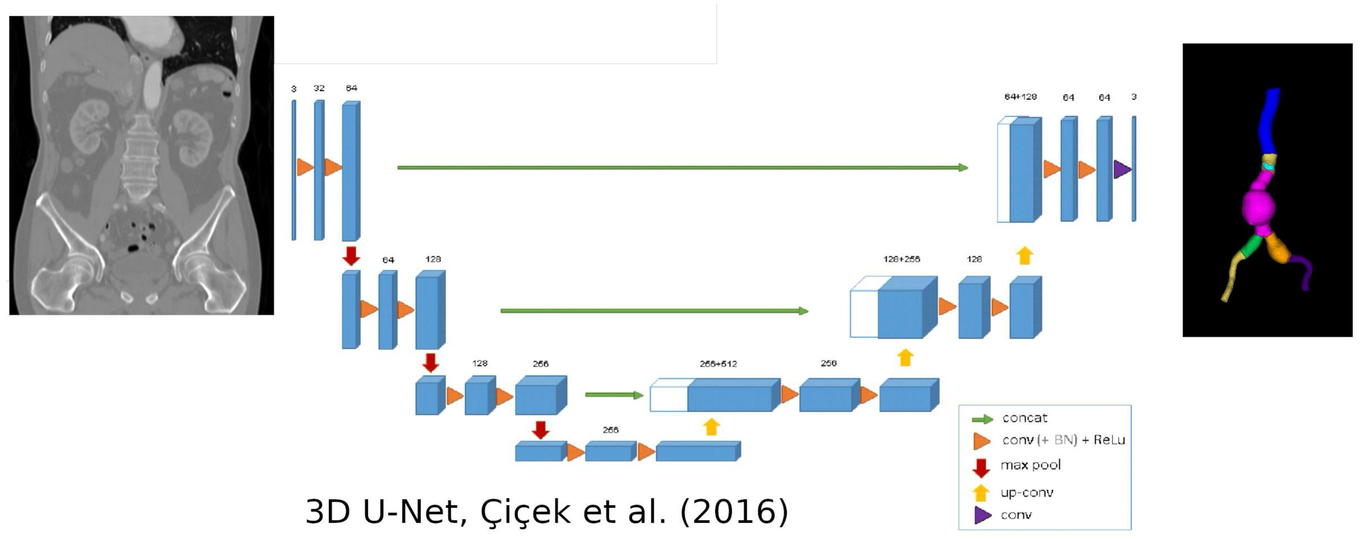

Figure 3. Schematic of semantic Whole Aorta Model (WhAM) prediction. A CT scan is passed as input to a 3D U-Net (Çiçek et al., 2016). The network outputs multi-class segmentation of the aorta, where each color represents a different anatomical region.

AVA accuracy was assessed by comparison of measurements produced by manually drawing around the outer contour of the aorta on centerlined CT scans (n=268 patients). Data labeling was carried out using a combination of an external labeling company and internal labelers. Multiple rounds of quality assurance, both automated and by experts, were carried out on each dataset.

We also assessed AVA on processed patient datasets ('Maps') derived from CT aortograms on patients undergoing aortic procedures in >50 hospitals (US/European) since 2015 (n=6140). Data from our own institution (n=553) was separately analyzed for comparison. Follow-up Map data was analyzed for volume changes in the subset of patients who had scans at 3-6 months and a second scan 6-24 months post-procedure (n=1238 overall, n=142 local). Aortic sac regression or growth were defined as change ≥10ml between scans.

Results

Tables I and II shows volume accuracy measured by Dice score (0-1) and absolute volume error (ml). Median volume error was 6.2ml and median Dice 0.95. Only 2.6% (7/268) patients had significant error >50ml due to segmentation errors. After data upload, volume analysis took less than 10 seconds for each scan.

Summary Statistic	Dice Score
Median	0.95
25th percentile	0.90
5th percentile	0.82

Table I: Dice score volume accuracy

Summary Statistic	Absolute volume error
Median	6.2 ml
75th percentile	11.8 ml
95th percentile	30.8 ml

Table II: Volume accuracy presented as absolute error in milliliters

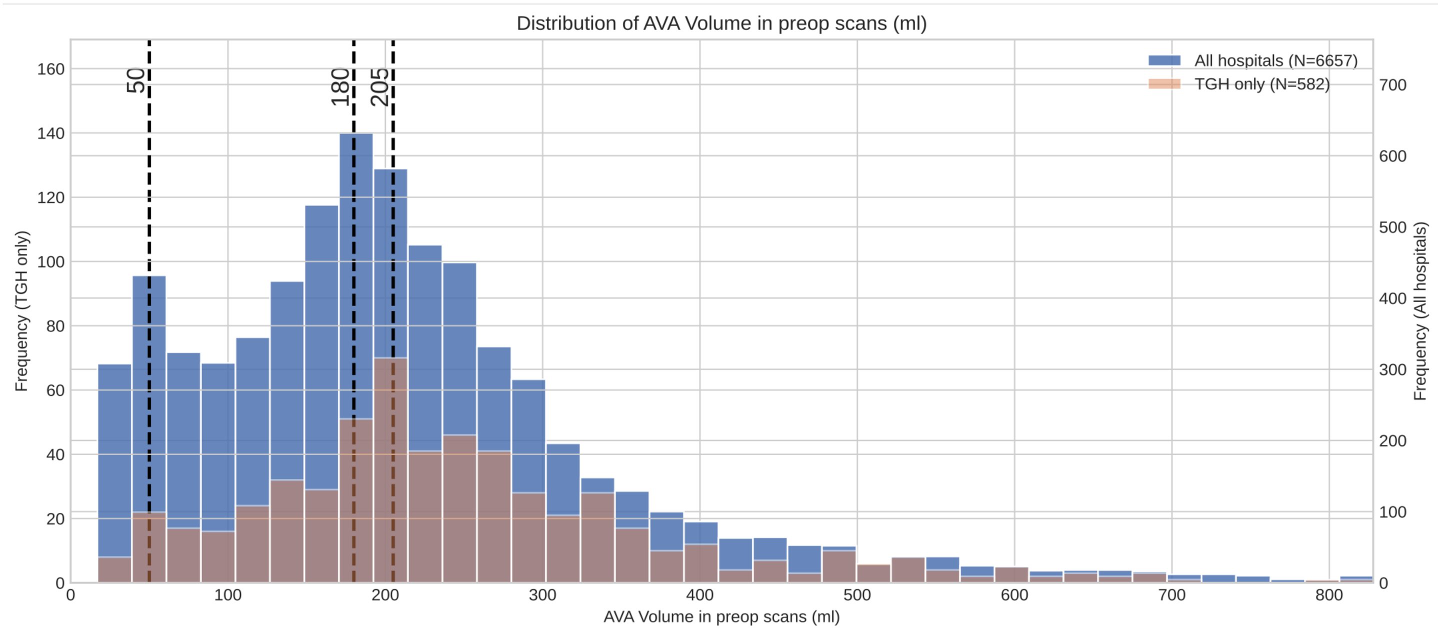

Figure 4. Histograms showing the volume distribution for the overall dataset and from our own institution. The overall volume distribution was bimodal, corresponding to the case mix in this dataset, the higher mode (180ml) represents aortic aneurysm cases which had a large abdominal component, the lower mode (50ml) represents other cases where the abdominal aorta was a normal size most often in patients with thoracic or arch pathology.

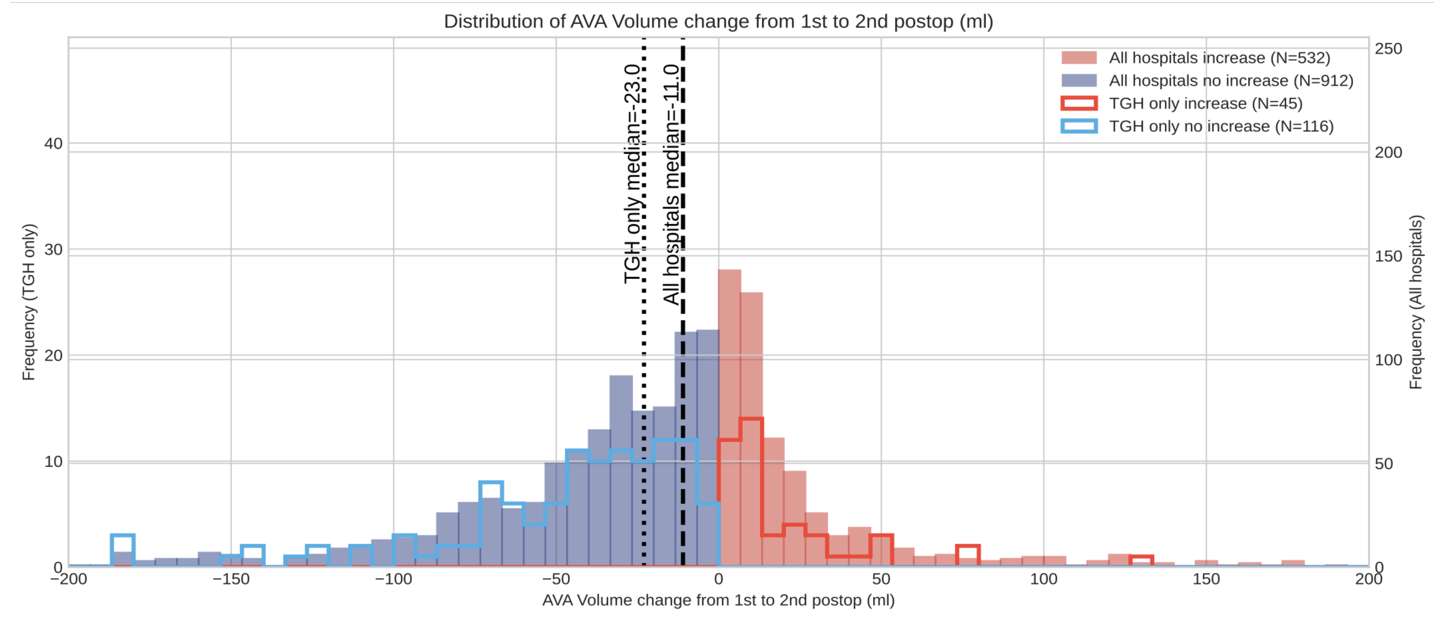

Figure 5. Histograms showing volume changes for the overall dataset and from our own institution. Values to the right of zero, colored red, represent expansion. Values the left of zero, colored blue show sac regression. Aortic sacs showed median regression of 11ml (overall) and 23ml (local).

Group	Patients (n)	Expansion (%)	Stable (%)	Regression (%)
Overall	1238	21.3	28.4	50.3
Local	142	14.0	25.4	60.6

Table III: Aortic volume comparison at 3-6 vs 6-24 months. "Stable" was defined as a change in volume <10ml.

Discussion & Conclusions

WhAM, implemented in Cydar's AVA programming, demonstrates accurate volumetric measurement validated by high Dice score and minimal absolute volume error.

While the rate of significant volume error was minimal (2.6%), predictive factors on CT imaging for segmentation errors remain unknown.

Current surveillance guidelines post-EVAR suggest initiating workup for reintervention if sac diameter growth ≥5mm, although these parameters have not been defined for volume.[6]

Implementation into clinical practice will be aided by integration into CT imaging platforms such that radiology reports can easily extrapolate the AI-assisted volumetric dimensions to aid clinical decision-making.

References

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