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EO - data collection, analysis, manuscript
IN – data analysis
AE - data collection, manuscript
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JRB - study design, manuscript
PWS - study design, manuscript

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EO - data collection, analysis, manuscript
IN – data analysis
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Abstract

Introduction

Visceral artery aneurysms (VAAs) are rare with a reported incidence of 0.1 to 2%. However, VAAs are clinically important and can present as life-threatening ruptures that require emergency treatment. The aim of this study was to review our experience with managing VAAs.

Methods

Retrospective analysis of a prospectively collected database was performed of 88 patients diagnosed with VAA over 15-year period (2006-2021). Aneurysm size was compared over time using the repeated measures mixed effects model.

Results

There were 108 VAAs identified in 88 patients, with a mean age of 74.7 years, SD 12.6 (age at presentation or first scan). Of these, 47 (43.5%) were splenic artery aneurysms with a median initial size of 15 mm, 36 (33.4%) were mesenteric artery aneurysms with a median initial size of 14.5 mm and 25 (23.1%) were renal artery aneurysms with a median initial size of 11 mm. Overall initial median size of the VAA's was 15mm. There is no statistically significant correlation between aneurysm growth rate and any medications or co-morbidities. In 88 patients, small VAAs (≤25 mm) were monitored with surveillance imaging with mean surveillance time of 72.7 months and median time of 65 months.

Conclusion:

This study confirms that VAAs < 25 mm do not show significant expansion. The important message is that none of 88 patients VAA's increased in size to require treatment. Our study suggests that it may be safe to extend the surveillance interval for small VAAs to 5 years.

Introduction:

Visceral artery aneurysms (VAAs) are rare with a reported incidence of 0.1 to 2% in the adult population[1-3]. VAAs are defined as aneurysms involving the coeliac, renal, superior mesenteric, and inferior mesenteric arteries as well as their associated branches. These aneurysms are incompletely understood given the rare nature of the disease, however, VAAs remain important as the mortality rate of diagnosed ruptures is at least 10%[4].

The splenic artery is most commonly affected (60% of cases), followed by the hepatic artery (20%). Concomitant aneurysms are found in up to one third of patients with visceral artery aneurysms.[5] Most commonly, aneurysms of the visceral arteries are incidental findings. These are identified when abdominal imaging is performed for other reasons, and may be

diagnosed on abdominal X-rays, ultrasound, computed tomography (CT) or magnetic resonance imaging (MRI).[6]

The clinical presentation is nonspecific in most cases; pain may occur if there is impending rupture or signs of mesenteric ischaemia due to thrombosis or embolism. CT angiogram allows for accurate diagnosis, anatomical characterisation, and interventional planning, and is generally the preferred imaging method.

Whilst most of the studies of VAAs are historical, recent contemporary studies with large numbers of VAAs[7, 8] have added to our knowledge. The European Society of Vascular Surgery (ESVS) published guidelines on Management of the Diseases of Mesenteric Arteries and Veins[9], which include recommendations and guidelines for the diagnosis, treatment and follow-up of visceral artery aneurysms. The Society for Vascular Surgery (SVS) has also published and updated their guidelines on the care of patients with aneurysms of the visceral arteries. They include evidence-based size thresholds for repair of aneurysms of renal, splenic and mesenteric arteries. The main difference between the ESVS and SVS guidelines is the change in treatment threshold, which has increased from 25 mm to 30mm[10].

The aim of this study was to review our experience (the largest single centre experience in the UK) with a view to defining the natural history and long-term outcomes of VAAs surveillance scans.

Methods:

Retrospective data analysis from a single vascular centre was performed of 88 patients diagnosed with VAA over 15-year period (2006-2021). VAA was defined as a lesion of the splanchnic vasculature that is 1.5 times the size of the native vessel on axial imaging. Visceral aneurysms were grouped into 3 categories: renal, splenic and mesenteric artery (coeliac, gastro- duodenal, hepatic, pancreatico-duodenal, Superior mesenteric artery and Inferior mesenteric artery).

Patient consent was not obtained due to the retrospective nature of the study and ethical approval was not required. Information about patient demographics, aneurysm type and size and surveillance were recorded.
Radiological reports (CT, MRI and USS) for each patient were used to record the size of aneurysms at initial presentation and each subsequent presentation. The very few patients who had initial diagnosis of VAA on USS underwent supplementary CT angiogram to confirm the anatomical location and size of the aneurysm. Where there was no change in size of aneurysm reported, aneurysm size was reported as remaining stable. Where there was no further follow up, only a single size and single time point were recorded. Data were analysed according to anatomical features such as aneurysm location, diameter and aneurysm status. All the radiological images were reconstructed into 3D software (TeraRecon, Inc.) and reported by 2 senior vascular interventional radiologists.

Patients who had thrombosed VAAs on axial imaging or pseudoaneurysms, transferred to another geographical area and patients who were lost to follow up were excluded from this study. Those who died during the study period were included and the cause of death was investigated using death certificates, coroner's report and contacting their general practitioner (GP).

Statistical analysis

Repeated measurements of VAA size taken from the same participant are correlated and this correlation needs to be accounted for in the analysis. VAA size measured from repeated follow-up scans is analysed using a linear mixed effect model that has fixed effects of scan number and VAA type with subject as a random effect. The aim is to estimate the effect of follow-up scan number on VAA size. Due to the nature of the retrospective data, repeated scans are not taken at regular time intervals: the data are unbalanced therefore we use an unstructured covariance matrix in the linear effects model. Scan number 1 to 15 is a proxy for time due to the high variability of time between each scan for different patients. The effect of scan number and VAA type on VAA size will be estimated with a 95%CI. The assumptions of the model will be assessed using graphical methods: a Q-Q plot of the residuals from the model and plots of residuals versus fitted values. To establish statistical equivalence between VAA aneurysms, TOST (two one-sided t-tests) equivalence test was performed.

Results

There were 108 VAAs identified in 88 patients, with a mean age of 74.7 years, SD 12.6 (age at presentation or first scan-Table 1). Of these, 47 (43.5%) were splenic artery aneurysms with a median initial size of 15 mm, 36 (33.4%) were mesenteric artery aneurysms with a median initial size of 14.5 mm and 25 (23.1%) were renal artery aneurysms with a median initial size of 11 mm. Overall initial median size of the VAA's was 15mm (Table 2).

All VAAs were incidentally diagnosed during routine urological or surgical radiological investigations. Characteristics of the study group are shown in Table 1. There is no statistically significant correlation between aneurysm growth rate and any medications or co-morbidities.
In this study, 108 small asymptomatic VAAs (≤25 mm) were under surveillance, 81% remained stable in size during a mean surveillance time of 72.7 (45.9) months, and a median surveillance of 65.0 months (Table 1).

During the surveillance period, the study cohort demonstrated a low aneurysm growth rate. The overall mean growth rate was 0.060 mm/month, SD (0.602)**,** with 95% confidence interval [**−**0.063 to 0.184] mm/month, suggesting no statistically significant increase in aneurysm size over time. Among the aneurysm subtypes, mesenteric aneurysms showed the highest mean growth rate at 0.190 mm/month**,** while renal and splenic aneurysms

demonstrated slight negative mean growth rates −0.018 mm/month and −0.002 mm/month**,** respectively, indicating stable sizes during follow-up, (Table 1).

Confidence intervals were narrow and centred close to zero, indicating no detectable trend toward growth or regression within the limits of this study's power (Table 3).

TOST (two one-sided t-tests) equivalence test was performed, based on the smallest effect size of interest i.e. a growth rate of ≥0.5mm/year. The mesenteric aneurysms have a mean growth rate of 0.2396 mm/year, 95% CI [-0.2301, 0.7094]. The Renal aneurysms have a mean growth rate of -0.0234 mm/year 95% CI [-0.1196, 0.0729]. The Splenic aneurysms have a mean growth rate of -0.0043 mm/year 95% CI [-0.0298, 0.0212], (Table 4). These lies entirely within the range -0.5mm/year to 0.5mm/year. Therefore, there is no meaningful change.

Despite this extended follow-up period of 6 years, aneurysm sizes remained relatively unchanged. This has strengthened the reliability of growth rates by allowing repeated measurements over time and reducing the influence of short-term variability. Further supporting the conclusion that these aneurysms exhibited minimal growth during long-term surveillance.

There was a total of 7 (8.0%) deaths in the cohort, two from metastatic lung cancer, three from community-acquired pneumonia and two from myocardial infarction. There was no VAA related mortality.
Patients had a mean of 10 surveillance scans over 15 years. Computed tomography angiography (CTA) was the most common surveillance scan (75%) followed by ultrasound scan (16%) and MRI (9%).

The mean length of surveillance across different types of VAA**,** where mesenteric aneurysms show the longest follow up (Figure 1). The overall mean VAA size (mm) by VAA type across follow-up scan, (Figure 2).

During the study period, 7 VAAs were repaired, 4 were >25mm at diagnosis and 3 were symptomatic. Of these, 4 were treated using endovascular technique (3 coil embolisation and one covered stent) and 3 had open surgery (1 ligation and 2 interposition graft). These patients were included in the study (in a separate patients group) accounted for the analysis.

Discussion

VAAs represent a rare pathology. The first reported successful operative repair was performed by Kehr in 1903; it consisted of ligation of a true hepatic artery aneurysm.[1] Since Debakey and Cooley, who described their repair of a mycotic superior mesenteric artery aneurysm[2], evidence has been steadily accumulating in the vascular literature. The ESVS has published mesenteric disease guidelines including VAA management[1]. However, the natural history of VAA remains a relative mystery and decision-making is complicated because of

the lack of available surveillance data and absence of prospective comparison and meta-analysis of treatment strategy.

Most large case series involving the management of VAAs have included an observational cohort, with encouraging results[3, 4,5,6,7-10]. Although ESVS recommended 2-3 years surveillance for asymptomatic VAA with a diameter of less than 25mm (class IIb) evidence[11], Corey et al. which is the largest study of the natural history of VAAs to date (264 VAA's in 250 patients) stated that VAAs less than 20mm in size that are asymptomatic show little to no growth and carry a negligible risk of rupture.[7]
The goal of this retrospective study was to review our institution's experience with VAAs that were either monitored or repaired at diagnosis in an effort to clarify whether there is a need for frequent surveillance of VAA at 2-3 years, given the benign nature of degenerative VAA and low risk of rupture.

Thus, our results support the notion that asymptomatic VAAs ≤25 mm at diagnosis rarely grow over time as 81% remained stable in size, which raises the question whether there is any benefit in continuing surveillance scans for patients presenting with small VAAs.

The radiation exposure associated with CT has increased substantially over the past two decades, and efforts need to be undertaken to minimize radiation exposure from CT, including reducing unnecessary studies, reducing the dose per study, and reducing the variation in dose across patients and facilities. Patient outcomes studies have helped to define when CT leads to the greatest benefit, and when these studies may have no impact, so that the radiation may be a greater risk than the benefit expected from the examinations. CTA is the scan of choice in most UK hospitals for VAA surveillance. The median effective dose of an abdomen and pelvis CT is often quoted as 8–10 mSv. Smith-Bindman reported for a multiphase abdomen and pelvis CT, the median effective radiation dose was 31 mSv, and the corresponding median adjusted lifetime attributable risk of cancer was 4 cancers per 1,000 patients[12]. This small increase in radiation-associated cancer risk for an individual can become a public health concern if large numbers of patients, some of young age, undergo increased numbers of CT screening procedures of uncertain benefit. Therefore, we believe regular surveillance scans for the patients with small VAAs leads to increase exposure to radiation despite the benign nature of the disease.

What makes this study different from previous reports is the significantly longer surveillance time with a median of 65 months (mean surveillance time 72.7 months). As none of the VAAs in this study reached the threshold for treatment or even showed significant increase in size after 6 years of surveillance, we recommend reducing the frequency of surveillance.

This study has limitations. It is a single-centre, observational study. Despite including all patients over a 15-year period, the population size is small with many patients having irregular time between follow-up scans or being lost to follow-up. Although this study is one of the largest in VAA surveillance to date and the only one to monitor patients for more than 3 years, larger multicentre studies or international registries of such patients are required to further determine the ideal surveillance intervals and protocols.

Conclusion:

This study confirms that small VAAs (<25 mm) does not show significant expansion. We suggest that it may be safe to extend the surveillance interval for small VAAs to 5 years.

Review Board Approval

Norfolk and Norwich University Hospital NHS Trust. Ethics approval not needed. Internal Review Board (IRB) approval from hospital clinical research and audit department was obtained for data collection, analysis & publication.

Conflict of interest

None

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Figure legends:

Figure 1: The mean length of surveillance in months across different types of visceral aortic aneurysms

Figure 2: Observed mean visceral aortic aneurysms size (mm) by VAA type across follow-up scan number.

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Table 1: Baseline characteristics, aneurysm size measurements, growth rates, and surveillance duration by visceral aneurysm type for patients under the VAA surveillance

	Aneuyrsm Types			Overall
	Mesenteric	**Renal**	**Splenic**	
Female N (%)	16 (14.8%)	17 (15.7%)	37 (34.3%)	55 (62.5%)
Male N (%)	20 (18.5%)	8 (7.4%)	10 (9.3%)	33 (37.5%)
Total N (%)	36 (33.3%)	25 (23.1%)	47 (43.6%)	88 (100%)
Age				
Mean (SD)	Mean Age 77.1 (10.9 SD)	Mean Age 74.4 (13.5 SD)	Mean Age 73.8 (13.1 SD)	Mean Age 74.7 (SD 12.6)
Initial size (mm)				
Mean (SD)	19.5 (15.5)	20.0 (19.6)	16.2 (8.5)	18.1 (13.9)
Median [Q1, Q3]	15.0 [13.0,18.0]	12.0 [10.0,15.0]	15.0 [9.0,22.0]	15.0 [11.0,19.0]
Final size (mm)				
Mean (SD)	20.6 (17.8)	20.7 (25.8)	16.1 (7.8)	18.6 (16.4)
Median [Q1, Q3]	15.0 [13.0,20.0]	12.0 [10.0,16.0]	15.0 [11.0,22.0]	14.0 [11.0,20.0]
Length of Surveillance (months)				
Mean (SD)	73.2 (63.9)	71.1 (36.7)	72.9 (31.4)	72.7 (45.9)
Median [Q1, Q3]	53.0 [27.0,115.0]	64.0 [51.0,102.0]	72.0 [49.0,96.0]	65.0 [39.0,97.0]
Growth rate (mm/months)				
Mean (SD)	0.190 (1.023)	-0.018 (0.126)	-0.002 (0.069)	0.060 (0.602)
95% Confidence Interval	[-0.170–0.550]	[-0.077–0.041]	[-0.022–0.018]	[-0.063–0.184]

Table 2: VAA mean size at scan 1 (mm) and surveillance time (months) overall and by VAA type (N=88).

		Aneurysm type			
		Mesenteric	**Renal**	**Splenic**	**Overall**
	N (%)	36 (33.4%)	25 (23.1%)	47 (43.5%)	108
Size at scan 1 (mm)	mean	19.6	21.8	16.6	18.8
Size at scan 1 (mm)	median	14.5	11.0	15.0	15
Follow-up (months)	mean	74.2	74.7	71.7	66.9
Follow-up (months)	median	53	64	71	63

Table 3: Shows effect size of difference in adjusted mean by aneurysm type

Aneurysm type	**Standard error**	**Adjusted mean difference 95% confidence interval**	**P Value**
Mesenteric	0.02386	-0.014 [-0.066, 0.038]	0.5562
Renal	0.02228	-0.033 [-0.081, 0.016]	0.1702
Splenic	0.02232	-0.018 [-0.067, 0.031]	0.4343

Table 4: TOST (two one-sided t-tests) equivalence test of the visceral aneurysms

Aneurysms type	**Mean (mm/year)**	**95% Confidence interval**
Mesenteric	0.2396	[-0.2301, 0.7094]
Renal	-0.0234	[-0.1196, 0.0729]
Splenic	-0.0043	[-0.0298, 0.0212]

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Figure 1: The mean length of surveillance in months across different types of visceral aortic aneurysms

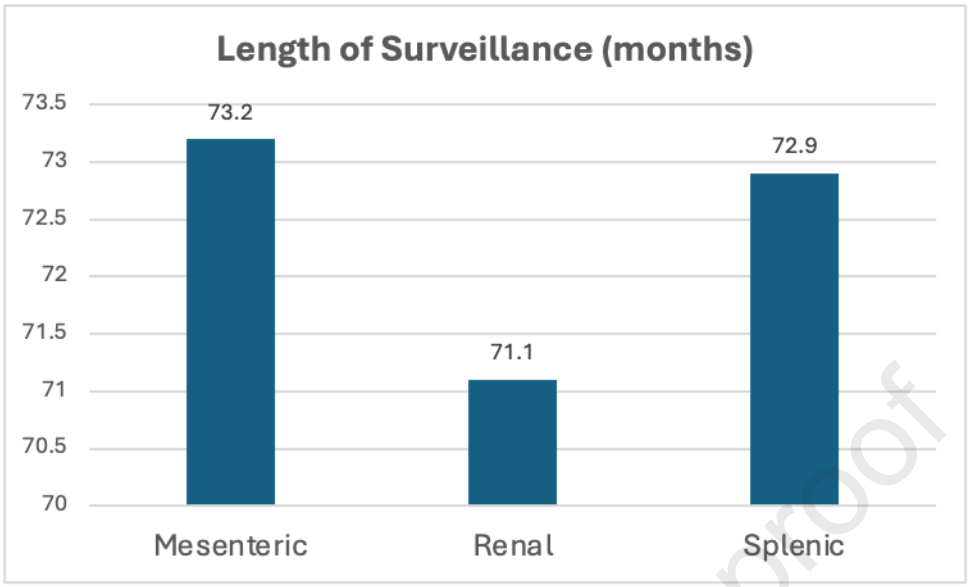

Figure 2: Observed mean visceral aortic aneurysms size (mm) by VAA type across follow-up scan number.