Prevalence of unruptured intracranial aneurysms: impact of different definitions. The Tromsø Study.

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Cover title: Prevalence of intracranial aneurysms

Tables: 6

Figures: 2

Keywords: Cerebrovascular Disease/Stroke, intracranial aneurysms, subarachnoid hemorrhage, epidemiology

Word count: Total 3330, abstract 249

Abstract

Background: Management of incidental unruptured intracranial aneurysms (UIAs) remains challenging and depends on their risk of rupture, estimated from the assumed prevalence of aneurysms and the incidence of aneurysmal subarachnoid hemorrhage. Reported prevalence varies, and consistent criteria for definition of UIAs are lacking. We aimed to study the prevalence of UIAs in a general population according to different definitions of aneurysm.

Methods: Cross-sectional population-based study using 3-dimensional time-of-flight 3 Tesla magnetic resonance angiography to identify size, type and location of UIAs in 1862 adults aged 40 to 84 years. Size was measured as the maximal distance between any two points in the aneurysm sac. Prevalence was estimated for different diameter cutoffs (≥1, 2 and 3 mm) with and without inclusion of extradural aneurysms.

Results: The overall prevalence of intradural saccular aneurysms ≥2 mm was 6.6% (95% confidence interval (CI) 5.4–7.6), 7.5% (95% CI 5.9–9.2) in women and 5.5% (95% CI 4.1–7.2) in men. Depending on the definition of an aneurysm, the overall prevalence ranged from 3.8% (95% CI 3.0–4.8) for intradural aneurysms ≥3 mm to 8.3% (95% CI 7.1–9.7) when both intra- and extradural aneurysms ≥1 mm were included.

Conclusion: Prevalence in this study was higher than previously observed in other Western populations and was substantially influenced by definitions according to size and extra- or intradural location. The high prevalence of UIAs sized <5mm may suggest lower rupture risk than previously estimated. Consensus on more robust and consistent radiological definitions of UIAs is warranted.

Non-standard Abbreviations and Acronyms

UIAs: Unruptured intracranial aneurysms

aSAH: aneurysmal subarachnoid hemorrhage

What is already known on this topic – The prevalence of UIAs in previous population-based studies varied from 1.9 to 7.0%. Definition of aneurysm was not consistent between studies.

What the study adds – The prevalence of intradural UIAs ≥2 mm was 6.6 %, which is higher than in previous studies of Western populations. The prevalence ranged from 3.8 to 8.3%, depending on definition according to size and extra- or intradural location.

How this study might affect research, practice or policy – A uniform definition of UIAs is necessary for comparison of prevalence across studies. The high prevalence of UIAs sized <5 mm may suggest lower rupture risk than previously estimated. This supports increased restraint with prophylactic repair of such lesions.

Introduction

Aneurysmal subarachnoid hemorrhage (aSAH) is a life-threatening subtype of stroke which affects relatively young people and has a high case fatality and morbidity.[1,2] With improved availability and utilization of advanced neuroimaging such as computer tomography angiography (CTA) and magnetic resonance angiography (MRA), unruptured intracranial aneurysms (UIAs) are found more frequently. Counselling and shared decision-making for patients with an incidentally detected UIA depend on the aneurysm´s rupture risk, estimated from the prevalence of UIAs and the incidence of aSAH in the population. In addition, individual risk factors for aSAH and treatment related complications must be considered.

The reported prevalence of UIAs varies with study design, study population and aneurysm characteristics.[3] In a systematic review and meta-analysis of 83 studies published before 2011, the overall prevalence in a population without comorbidity, mean age of 50 years and 50% men, was estimated to 3.2% (95% CI 1.9–5.2).[4] Since then, three cross-sectional population-based angiography studies have been published. The HUNT study in Norway reported a prevalence of 1.9% in 1006 subjects aged 50–65 years,[5] while the Rotterdam Scan Study reported a prevalence of 2.3% in 5800 participants with a mean age of 64.9 years.[6] A corresponding study of 4813 participants aged 35 to 75 years in Shanghai, China, found an overall prevalence of 7.0%.[7]

While intracranial aneurysms are defined as abnormal focal dilations of an artery in the brain, the exact definition based on size and intra- or extradural location may vary between studies. Both differences in definitions and the use of imaging techniques could influence the detection rate. In the present study, we aimed to determine the prevalence of UIAs in a general Norwegian population aged 40 years and older and explore how the definition of UIA influences prevalence estimates.

Material and Methods

Study participants

The Tromsø Study is a large longitudinal and multipurpose population health study of adult inhabitants in the municipality of Tromsø, Norway, started in 1974.[8,9] The study design is repeated cross-sectional surveys to which total birth cohorts and selected samples are invited. The seventh survey was conducted in 2015–2016 and consisted of two visits. The recruitment was based on the official population registry. All citizens aged 40 years and older (n=32 591) were invited to participate in the first visit, and 21 083 (64.7%) attended.

A subsample consisting of 75% who were randomly drawn from 10-year age bands in men and women and of 25% who had participated in the 2nd visit of the 6th Tromsø Study was invited to a second visit for various extended clinical examinations, and 8346 (90.2%) of the 9253 invited attended. Due to limited capacity for MRI, we chose to invite the 3027 participants who had also been examined with ultrasound of the carotid arteries to participate in a magnetic resonance imaging (MRI) study conducted in 2016–2017. Of these, 975 did not attend, 169 were excluded because of contraindications for MRI, and five were excluded because they had moved or died before the MRI examination. Of the 1878 subjects who underwent MRA scanning, images were missing in eight participants and image quality was deemed as insufficient for assessment of UIAs in seven participants. One participant later withdrew the consent and was excluded, leaving 1862 participants who were included in the final analysis (Supplementary Figure 1).

Cardiovascular risk factors

Information on smoking and drinking habits, medication use or prevalent cardiovascular disease such as history of stroke, coronary heart disease and diabetes was obtained from questionnaires. Standardized measurements of blood pressure, height and weight were

obtained by trained personnel. Serum total cholesterol and HDL cholesterol were analyzed by standard enzymatic methods. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Hypertension was defined as mean systolic blood pressure ≥140 mmHg and/or mean diastolic blood pressure ≥90 mmHg and/or use of blood pressure-lowering medication and/or self-reported hypertension.

MRI and MR angiography

Participants were scanned at the University Hospital of North Norway, Tromsø, with a 3 Tesla (3T) Siemens Skyra MR scanner (Siemens Healthcare, Erlangen, Germany). We used the 3D time-of-flight MRA sequence (3D-TOF-MRA) for detection of aneurysms and made maximum intensity projection (MIP) reconstructions, volume-rendered (VR) reconstructions and, when needed, additional single arterial segmentation to optimize the evaluation of aneurysm morphology from the source images. Aneurysms were measured on multiplanar reconstructions (MPR). Details about the technique are provided in the Supplemental material.

Aneurysm definition

All visible abnormal focal saccular dilatations were measured from center of the neck plane to the dome apex and then perpendicular to this axis. Additionally, any diameter between any two points in the aneurysm sac that was larger than these two diameters was recorded, and the maximum diameter defined the aneurysm size. Fusiform aneurysms (n=5) were excluded.

We categorized aneurysm locations on the internal carotid artery (ICA) according to the Bouthiller classification.[10] Aneurysms located in and distal to the clinoid segment (C5) were defined as intradural. The C7-segment of the ICA was further subdivided into the posterior communicating artery, the anterior choroid artery and terminus. We categorized

UIAs located to the anterior cerebral artery (ACA) as A1-segment, anterior communicating artery and distal anterior cerebral artery, the middle cerebral artery (MCA) as M1-segment, bifurcation of M1 and M2-segment, the posterior cerebral artery as P1-segment and P2-segment and vertebrobasilar arteries as basilar artery, superior cerebellar artery, posterior inferior cerebellar artery and anterior inferior cerebellar artery. The sizes were categorized as ≥1–1.9 mm, ≥2–2.9 mm, ≥3–4.9 mm, ≥5–6.9 mm, ≥7mm.

Intra- and interobserver agreement

Details about the assessment of aneurysms and intra- and interobserver agreement are provided in the Supplemental material. All images and reconstructions were evaluated twice by one experienced neuroradiologist (LHJ) and all aneurysms were measured by two experienced neuroradiologists (LHJ and MH). Interobserver discrepancies in measurements of UIAs were resolved by consensus between the two observers.

The Cohen's kappa for interobserver reliability on detecting aneurysms was 0.79 (SE 0.10). The interobserver intraclass correlation coefficient (ICC) for measurement of the size of the aneurysms was 0.93. The intraobserver ICC for the first reader was 0.98.

Ethics

The study was approved by the Regional Committee of Medical and Health Research Ethics North Norway (file no. 2014/1665) and carried out in accordance with relevant guidelines and regulations. All participants gave written informed consent.

All participants with vascular pathological findings judged to be clinically relevant were referred to the vascular neurosurgical outpatient clinic for clinical follow-up and management according to department policies. Similarly, incidental clinically relevant non-

vascular pathological findings were referred to the other specialist clinics at the University Hospital of North Norway, Tromsø.

The STROBE reporting guideline was used.

Statistical analysis

The data were analyzed with Stata for Mac (version 17: StataCorp LP, TX). Continuous variables are presented as means with 95% confidence intervals (CI) and categorical variables as percentages (95% CI). For the 1862 participants baseline variables were missing for body mass index (n=1), systolic blood pressure (n=6), smoking status (n=18), total cholesterol and HDL cholesterol (n=7), use of lipid-lowering medication (n=44), diabetes mellitus (n=33), history of stroke (n=73), history of coronary heart disease (n=1) and alcohol intake (n=12).

Differences between groups were evaluated using a two-sample t-test for summary data, and z-test was used to compare proportions in one sample.

In the primary analysis of prevalence in the population, we defined an aneurysm as an abnormal focal saccular dilatation of an intradural cerebral artery with a diameter ≥2 mm. We further explored how altered definitions for size (≥1.0 mm, ≥3 mm and ≥5 mm) and/or inclusion of UIAs located extradurally influenced the estimated prevalence.

Results

Characteristics of participants with and without aneurysms are shown in Table 1. The mean age of participants was 63.8 years and 52.6% were women. The proportion of participants with hypertension was larger in participants with UIAs than in those without, although not significant. The results were similar when the threshold for systolic blood pressure was set at ≥130 mmHg. The proportions who reported alcohol intake more than four times per week,

had diabetes and were current smokers were larger in participants with UIAs than in those without, but not significant. This did not change after age- and sex-adjustment.

A total of 131 intradural saccular aneurysms ≥2 mm was detected in 122 of the 1862 participants (Table 1), which gives a prevalence of intradural UIAs ≥ 2mm of 6.6% (95% CI 5.4–7.6). Three participants had three UIAs and three had two UIAs.

The overall and age- and sex-specific prevalences of UIAs are shown in Table 2. The prevalence was 7.5% (95% CI 5.9–9.2) in women and 5.5% (95% CI 4.1–7.2) in men. In women, prevalence was 4.5% (95% CI 2.1–8.1) in the 40–54 years age band, 8.2% (95% CI 5.2–12.1) in the 55–64 years age band, 8.3% (95% CI 5.7–11.7) in the 65–74 years age band and 8.6% (95% CI 4.5–15.6) in the 75–84 years age band. In men, prevalence was 5.1% (95% CI 2.2–9.8) in the youngest age band, 5.5% (95 % CI 3.0–9.2) in the 55–64 years age band, 6.5% (95 % CI 4.0–9.7) in the 65–74 years age band and 3.9% (95% CI 1.4–8.3) in those aged 75–84 years. There was no consistent difference in size of aneurysms between men and women (Supplementary Table 1).

Fifty-six of the 131 UIAs (42.7%) were in the internal carotid artery, fourteen (10.7%) in the anterior cerebral artery, fifty (38.2%) in the middle cerebral artery and eleven in the posterior circulation (8.4%) (Table 3).

The overall prevalence according to different definitions of UIAs was 3.8% (95% CI 3.0–4.8) for intradural aneurysms ≥3 mm, 7.4% (95% CI 6.2–8.6) when the cutoff was set at ≥1 mm and 8.3% (95% CI 7.1–9.7) when both intra- and extradural aneurysms were included (Table 4, Figure 1). Supplementary Figure 2 shows the distribution of all intradural UIAs by size.

Discussion

In the present study, the overall prevalence of intradural saccular UIAs ≥2 mm was 6.6%. The prevalence changed substantially depending on definition, both concerning threshold for size and intra- or extradural location.

The prevalence of UIAs in our study is significantly higher than those reported in previous population-based European studies. The prevalence in the HUNT study[5] and the Rotterdam Scan study[6] was 1.9% (95% CI 1.2–2.9) and 2.3% (95% CI 2.0–2.7), respectively. Our results are closer to the prevalence of 7.0% (95% CI 6.3–7.7) found in the Shanghai study.[7] It is likely that the differences between the studies, at least partly, are explained by differences in imaging techniques. Both the HUNT study and the Rotterdam Scan study used 1.5T MRI, while the Shanghai study and the present study used 3T (Table 5). Sailer and co-workers reviewed studies of the accuracy of MRA in diagnosing intracranial aneurysms and found that 3T performed better than imaging with lower field strengths.[11] The higher resolution and improved signal/noise ratio provided by 3T MRA improve the detection rate, particularly for UIAs smaller than 3 mm and UIAs located in the carotid siphon.[12-14]

Post-processing techniques also influence the detection rate. VR-reconstruction of 3D-TOF-MRA enables dynamic viewing from all directions instead of fixed reconstructions in standard planes, improving accuracy and reducing false-positive detections.[11,15] In the HUNT study,[5] 3D-TOF-MRA with evaluation of source images and fixed MIP was used, while proton density-weighted images (PDW) without reconstruction of the images with volume rendering technique was used in the Rotterdam Scan study[6] (Table 5).The present study and the Shanghai study[7] used 3D-TOF-MRA with reconstructions in MIP and VR and used single-artery highlighting technique when needed.[15]

Differences in the age distribution may also have contributed, but cannot fully explain the variation in prevalence between studies. The HUNT study[5] included participants aged 50-65 years (mean age 58.5 years) (Table 5). The age distribution in our study was similar to that

of the Rotterdam Scan study,[6] which included participants aged 45 years and older (mean age 64.9 years). Despite a lower mean age (52.1 years) of participants in the Shanghai study[7], the prevalence of UIAs was similar to our study.

Different definitions of aneurysms could also explain the differences in prevalence estimates between studies. The Shanghai study used the same threshold for size (≥ 2 mm) as we did, but also included extradural UIAs located in the C3- and C4-segments of the ICA (Table 5). The HUNT Study[5] and the Rotterdam Scan Study[6] did not provide exact definitions by size or intra- or extradural location. We chose not to include extradural UIAs in our main prevalence estimation because these aneurysms usually will not cause aSAH.[16] UIAs in the C5-segment, on the other hand, we defined as intradural. This is because the location of the dural rings, and most importantly the distal dural ring, cannot be reliably determined with MRI; hence UIAs in the C5-segment of the ICA are potentially intradural.[17]

The mean maximum size of the UIAs was 3.8 mm in our study, compared to 3.5 mm in the Shanghai study,[7] 5.6 mm in HUNT [5] and 4.5 mm in the Rotterdam Scan study.[6] This range can probably be explained by the use of 3.0 T 3D-TOF-MRA and improved post-processing abilities. Approximately 80% of the UIAs in the present study were smaller than 5 mm compared to 90% in the Shanghai study, and the proportions of UIAs with diameters below 10 mm were 99.2% and 99.5%, respectively.

The present study indicates that aneurysms as small as 1.0 mm can be detected with 3T MRA.[15,18] On the other hand, a very low size threshold increases the likelihood of false-positive findings due to limitations in the method regarding visualizing of small vessels as they get narrower. Therefore, detection and categorization of UIAs sized 1.0 - 1.9 mm should be interpreted with caution. In the present study, we detected 19 intradural aneurysms that were 1.0-1.9 mm. 43% (56/131) of aneurysms were as small as 2.0-2.9 mm (Supplementary Figure 2).

The prevalence increased with age in both women and men, except for the men in the oldest age group (75-84 years). It is unlikely that prevalent aneurysms regress in old age. Accordingly, the observed prevalence could be biased by the low sample size in this age-band, or by selection bias in the recruitment of old participants.

The PHASES (Population, Hypertension, Age, Size of aneurysm, Earlier SAH from another aneurysm, and Site of aneurysm) score for prediction of rupture assumes that aneurysms sized <7.0 mm carries a very low rupture risk.[19] Nevertheless, controversy exists about the management of UIAs <7.0 mm because they are a common cause of aSAH despite their low rupture risk.[20] Studies that stratify the risk by location and size indicate that small aneurysms are not a homogenous group. Aneurysms located in the posterior circulation and the posterior communicating artery,[21] as well as aneurysms sized 4-6 mm located in the anterior communicating artery or the distal anterior artery, have higher rupture risk than small aneurysms in general.[22] The assumed elevated risk of rupture according to these studies[19-22] applies to 29 (22%) of the 131 UIAs observed in the present study, 9 UIAs ≥7 mm and 20 UIAs <7mm (7 UIAs in the posterior communicating artery, 9 UIAs in the posterior circulation, and 4 UIAs 4-6 mm in the anterior communicating artery).

In a retrospective study of aSAH from the northern Norway region[23] the annual frequency of aSAH in the Tromsø population was 1.15 from aneurysms <5 mm and 1.84 from aneurysms ≥5 mm. Based on this and the observed prevalence of UIA in the present study, we estimated an annual risk of rupture of 0.07% for aneurysms <5 mm and 0.41% for aneurysms ≥5 mm. The low rupture risk of UIAs <5 mm supports restraint with prophylactic repair of such lesions.

Longitudinal follow-up studies and further analysis of aneurysm size and localization in aSAH patients compared to the MRA screening group from the same general population might provide additional knowledge on size- and location-specific rupture risk.

In accordance with the Shanghai study,[7] we found that most aneurysms were located to the ICA but with a significantly lower proportion (42.8% compared to 81% in the Shanghai study). The HUNT study[5] and the Rotterdam Scan study[6] reported 31.5% and 30% of the UIAS in the ICA, respectively. The inclusion of extradural UIAs in the Shanghai study and the lower field strength MRI technology in the HUNT and Rotterdam study probably contribute to this discrepancy. The proportion of UIAs in the ACA with branches was also comparable to the Shanghai study and lower than in the HUNT and Rotterdam studies.

There was a striking difference between our study and the Shanghai study with regards to the proportion of aneurysms located in the MCA (38.2% in our study compared to 4.1% in the Shanghai study) and, to a lesser extent, the proportion of aneurysms located in the posterior circulation (8.5% compared to 2.4%). The HUNT and Rotterdam studies reported proportions of MCA aneurysms comparable to those observed in our study, but a lower proportion of posterior circulation aneurysms. Other MRI-based prevalence studies from Asia report proportions of UIAs in the middle cerebral artery ranging from 9% to 28.6%.[12,22-26] The different location-distribution of UIAs between European and Asian population-based studies is interesting, especially the difference in the proportion of MCA aneurysms. This suggests that the distribution of UIAs is probably not the same in different populations, which should be considered when estimating rupture risk based on aneurysm location.

Strengths and limitations

The main strength of this study is the population-based study design, with a balanced age distribution. Another strength is the use of 3D-TOF-MRA performed on 3T MRI combined with post-processing abilities, including VR-3D reconstruction, to detect UIAs.

Measurements of aneurysms on MRI can be both under- and overestimated. In an in-vitro study from Japan, Takao and co-workers found that measurement of aneurysm height

was lower than in the actual model[27], and in VR 3D-TOF-MRA, there was an overestimation of the aneurysm neck.[28]. In our study, all measurements were done at MPR and not VR, as VR is more prone to errors. Furthermore, as the threshold for window width and window level was allowed to be changed when measuring UIAs, this could also lead to measurement errors, particularly for small aneurysms. Another limitation of 3D-TOF-MRA is the possibility of missing aneurysms with slow or turbulent flow due to loss of signal, particularly in large-sized aneurysms. Also, the analyses in this study were limited to aneurysm size and did not include other aneurysm related risk factors for rupture such as aneurysm morphology or growth.

The number of participants in this study was limited, resulting in relatively wide confidence intervals for the age- and sex-specific prevalence estimates, especially for the oldest age bands. Twenty-five percent of the participants were invited because of previous participation in the Tromsø Study, which may have led to some degree of selection bias. The mean age and the proportion of women were somewhat higher in non-attendees (mean age 65.0 years, 55.0% women) than in attendees of the MRI study (mean age 63.8 years, 53.2% women). Lower participation rate in the oldest age groups due to disease or disability may have led to underestimation of UIA prevalence in the elderly.

Another limitation is that we did not have information on family history or genetic conditions associated with increased prevalence of UIA. Finally, the findings may not apply to other populations and ethnic groups.

Conclusions

The overall prevalence of UIAs ≥2 mm in adults aged 40-84 years in our study was 6.6%. This is higher than previously observed in Western populations. Depending on definition by size and intra- or extradural location, the prevalence ranged from 3.8% for intradural

aneurysm ≥3 mm to 8.3% for intra- and extradural aneurysms ≥1 mm. The high prevalence of UIAs sized <5 mm may suggest lower rupture risk than previously estimated. More robust and consistent radiological definitions of intracranial aneurysms are needed to compare results from different populations and to improve shared decision-making in management of individuals with incidental unruptured intracranial aneurysms.

Funding

LHJ has governmental funding (doctoral scholarship) from the Northern Norway Regional Health Authority (Grant SFP 1283-16). The MRI/MRA study was funded by the Northern Norway Regional Health Authority (Grant SFP 1271-16).

Disclosures

None

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Table 1

Table 2

Table 3

Table 4

Table 5

Figure 1

Supplemental materials

STROBE check list

SUPPLEMENTAL MATERIAL

MRI and MR angiography – supplementary text

Supplementary Figure 1. Flow chart of participation in the study

Supplementary Table 1: Distribution of unruptured intradural saccular aneurysms* across categories of size, stratified by sex. The Tromsø Study.

Supplementary Figure 2. Distribution of 150 intradural UIAs by size including UIAs from 1.0-1.9 mm.

MRI and MR angiography

Participants were scanned at the University Hospital of North Norway, Tromsø, with a 3 Tesla (3T) Siemens Skyra MR scanner (Siemens Healthcare, Erlangen, Germany). In most examinations, a 64-channel head coil was used. A larger 20-channel head coil was used in the examination of 39 participants because of either head size or slight claustrophobia. The MRI protocol consisted of a 3-dimensional (3D) T1-weighted sequence, a 3D fluid-attenuated inversion recovery sequence (FLAIR), a susceptibility-weighted sequence (SWI) and a 3D time-of-flight MRA sequence (3D-TOF-MRA). The total scan time was 22 minutes. In this study, we only used the 3D-TOF MRA images. These were acquired with a 3D transversal fast low angle shot sequence with flow compensation; repetition time/echo time 21/3.43 ms, parallel imaging acceleration factor 3, field of view 200 x 181 mm, slice thickness 0.5 mm, 7 slabs with 40 slices each. Reconstructed image resolution was 0.3 x 0.3 x 0.5 mm.

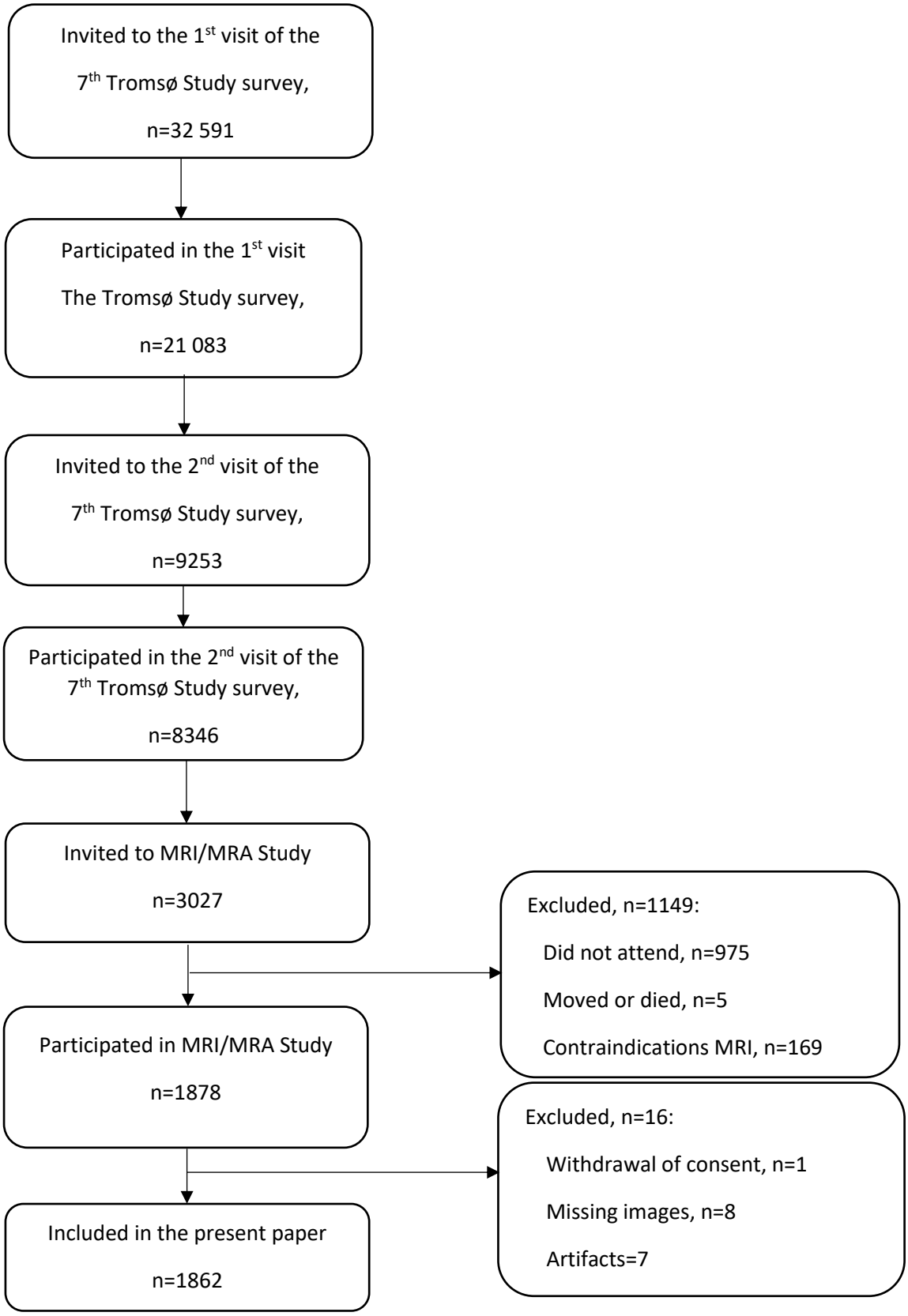
Assessment of aneurysms and intra- and interobserver agreement

Assessment of aneurysms was done on a Sectra workstation, Sectra IDS7 (v22.1.12.4835), by two experienced neuroradiologists (MH and LHJ), using source images, maximum intensity projection (MIP) reconstructions, multiplanar reconstructions (MPR) and volume-rendered (VR) reconstructions of the 3D-TOF-MRA images. When needed, additional single arterial segmentation was made to optimize the evaluation of aneurysm morphology.

All images and reconstructions were evaluated twice by one of the observers (LHJ). The interobserver reliability was assessed in 100 examinations, drawn from a random sample of 160 examinations enriched with 30 known aneurysms, which were read by both observers.

All aneurysms were measured by both observers. Aneurysms were measured on MPR of the axial 3D-TOF-MRA source images. The threshold for window width and window level was allowed to be changed to discriminate between small aneurysms and infundibula.

Supplementary Figure 1. Flow chart of participation in the study



Supplementary Table 1: Distribution of unruptured intradural saccular aneurysms* across categories of size, stratified by sex. The Tromsø Study.

Aneurysm size	Women	Men	Total
2–2.9 mm	31 (37.8)	25 (51.0)	56 (42.8)
3–4.9 mm	33 (40.3)	15 (30.6)	48 (36.6)
5–6.9 mm	12 (14.6)	6 (12.3)	18 (13.7)
≥ 7 mm	6 (7.3)	3 (6.1)	9 (6.9)†
Total	82 (100)	49 (100)	131 (100)
Mean aneurysm size (SD), mm	3.91 (1.83)	3.63 (1.66)	3.81 (1.77)

Values are numbers (percentages) of aneurysms.

*Observed in 122 participants

† Of the 9 UIA with size ≥ 7 mm, 3 were located to the carotid artery (including 1 in the posterior communicating artery), 1 in the anterior communicating artery, 2 in the posterior circulation and 3 in the middle cerebral artery.

Supplementary Figure 2. Distribution of 150 intradural UIAs by size including UIAs from 1.0-1.9 mm.

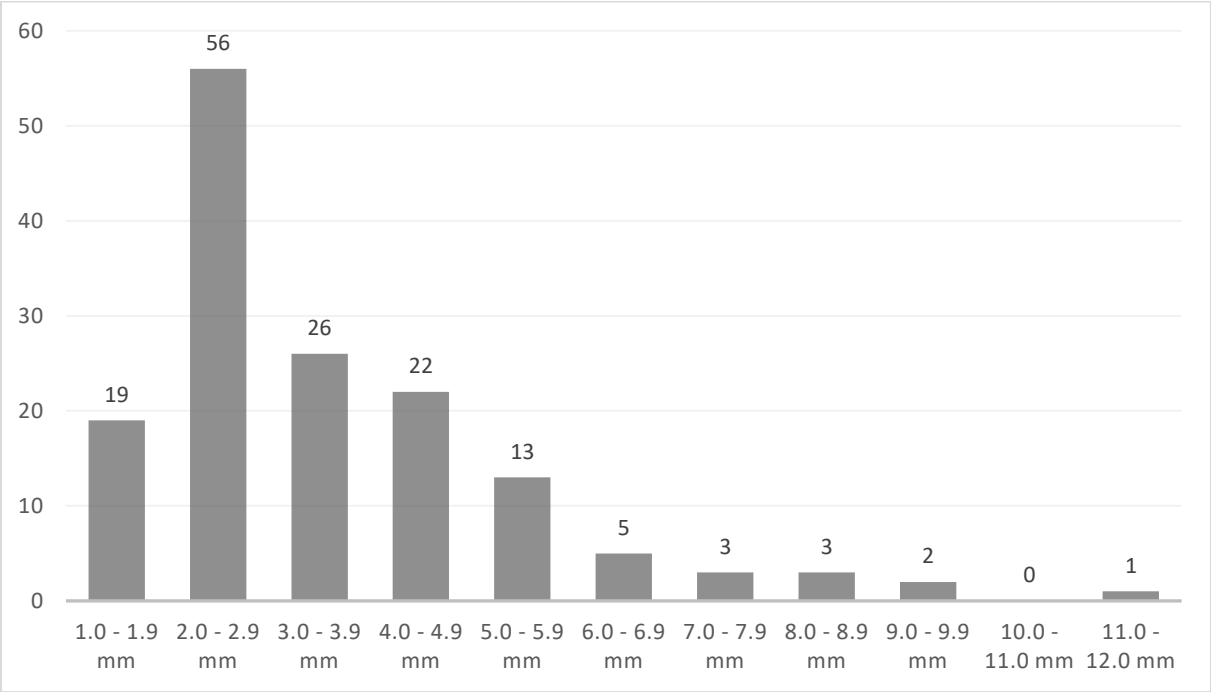


Figure 1. Prevalence of intradural unruptured intracranial aneurysms (UIAs) according to different definitions by size, stratified by age group. The Tromsø Study.

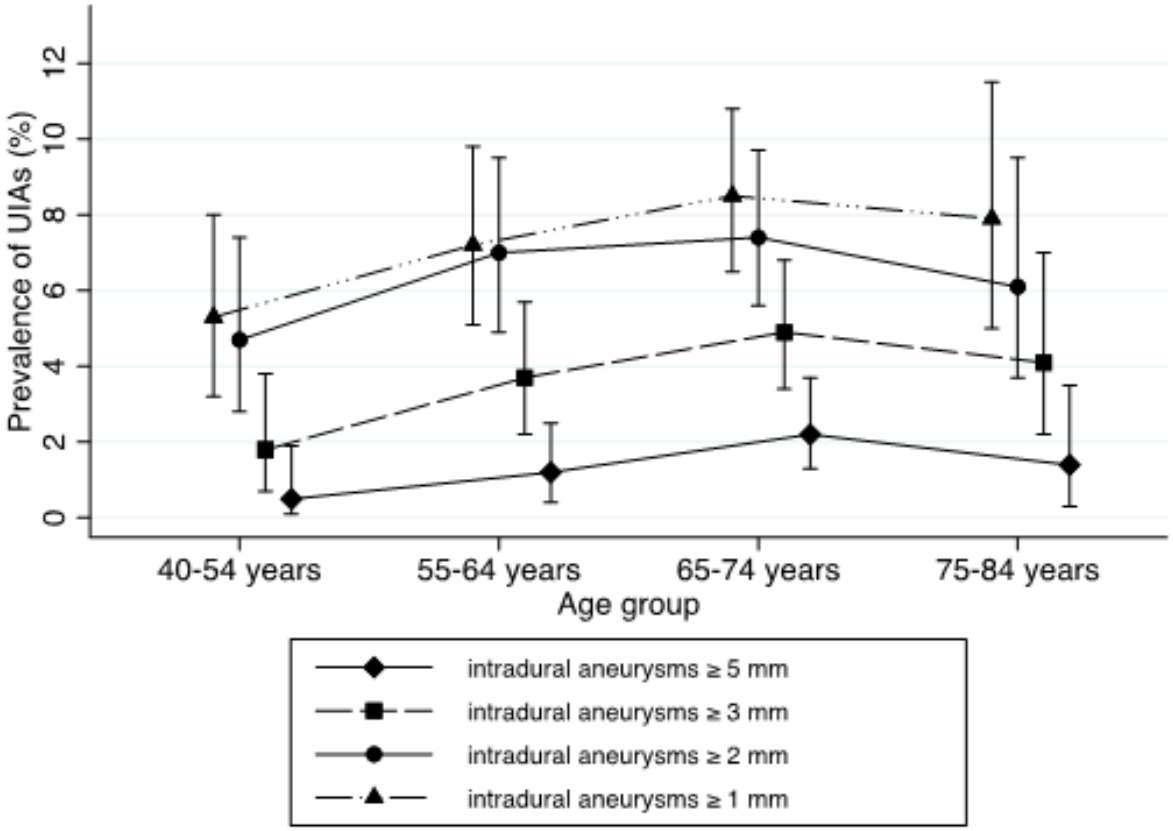


Table 1. Characteristics of participants with and without unruptured intradural saccular aneurysms ≥2 mm. The Tromsø Study.

	All participants	With aneurysm	Without aneurysm
Number (%)	1862	122 (6.6)	1740 (93.4)
Mean age, years	63.8 (63.3–64.3)	64.6 (62.9–66.3)	63.8 (63.3–64.3)
Female sex	53.2 (50.9–55.5)	60.7 (51.4–69.4)	52.6 (50.3–55.0)
Mean body mass index, kg/m2	27.1 (26.9–27.3)	26.5 (25.8–27.3)	27.2 (27.0–27.4)
Hypertension	53.7 (51.4–55.9)	61.5 (52.2–70.1)	53.1 (50.7–55.5)
Mean systolic blood pressure, mmHg	134.0 (133.0–134.9)	136.8 (133.2–140.5)	133.8 (132.8–134.8)
Current smoking	13.0 (11.5–4.6)	15.1 (9.2–22.8)	12.8 (11.3–14.5)
Total cholesterol, mmol/L	5.51 (5.46–5.56)	5.54 (5.32–5.75)	5.50 (5.45–5.56)
HDL cholesterol, mmol/L	1.63 (1.61–1.65)	1.68 (1.58–1.78)	1.63 (1.60–1.65)
Use of lipid-lowering medication	23.6 (21.7–25.6)	27.4 (19.5–36.4)	23.3 (21.3–25.4)
Diabetes mellitus	6.3 (5.2–7.5)	9.0 (4.6–15.6)	6.1 (5.0–7.3)
History of stroke	3.1 (2.3–4.0)	3.4 (0.9–8.5)	3.1 (2.3–4.1)
History of coronary heart disease	10.5 (9.1–12.0)	10.7 (6.0–17.5)	10.5 (9.1–12.0)
Alcohol intake more than four times per week	8.1 (6.9–9.4)	11.8 (6.6–19.0)	7.9 (6.6–9.2)

Continuous variables are presented as mean (95% CI), categorical variables as percentages (95% CI).

Table 2. Prevalence (%) of unruptured intradural saccular aneurysms ≥2 mm stratified by age group and sex. The Tromsø Study.

	Total	40-54 years	55-64 years	65-74 years	75-84 years
Men					
No. with aneurysms/No. of participants	48/872	8/157	13/236	21/325	6/154
Proportion with aneurysms (95% CI)	5.5 (4.1–7.2)	5.1 (2.2– 9.8)	5.5 (3.0–9.2)	6.5 (4.0–9.7)	3.9 (1.4–8.3)
Women					
No. with aneurysms/No. of participants	74/990	10/224	23/279	29/348	12/139
Proportion with aneurysms (95% CI)	7.5 (5.9– 9.2)	4.5 (2.1–8.1)	8.2 (5.2–12.1)	8.3 (5.7–11.7)	8.6 (4.5–15.6)
Total					
No. with aneurysms/No. of participants	122/1862	18/381	36/515	50/673	18/293
Proportion with aneurysms (95% CI)	6.6 (5.4–7.6)	4.7 (2.8–7.4)	7.0 (4.9–9.5)	7.4 (5.6–9.7)	6.1 (3.7–9.5)

Table 3: Location of unruptured intradural saccular aneurysms ≥2 mm in men and women. The Tromsø Study.

Aneurysm site	Women	Men	Total
Internal carotid artery*	34 (41.5)	22 (44.9)	56 (42.7)
Anterior cerebral artery†	7 (8.5)	7 (14.3)	14 (10.7)
Middle cerebral artery	33 (40.2)	17 (34.7)	50 (38.2)
Posterior cerebral/vertebrobasilar artery	8 (9.8)	3 (6.1)	11 (8.4)
Total	82 (100)	49 (100)	131 (100)

Values are number (percentage) of aneurysms.

*including 21 UIAs in the C5-region and 8 in the posterior communicating artery

†including 12 UIAs in the anterior communicating artery

Table 4. Observed unruptured aneurysms (UIAs) by size and location (intradural only and intra- and extradural).The Tromsø Study.

UIAs	1.0-1.9 mm	2.0-2.9 mm	≥3.0 mm	Total UIAs	Observed in participants	Prevalence (%) (95 % CI)
Intradural ≥ 1 mm	19	56	75	150	137	7.4 (6.2-8.6)
Intra- and extradural ≥ 1 mm	22	65	85	172	155	8.3 (7.1-9.7)
Intradural ≥ 2 mm		**56**	**75**	**131**	122	6.6 (5.4-7.6)
Intra- and extradural ≥ 2 mm		65	85	150	137	7.4 (6.2-8.6)
Intradural ≥ 3 mm			75	75	71	3.8 (3.0-4.8)
Intra- and extradural ≥ 3 mm			85	85	80	4.3 (3.4-5.3)

*The total prevalence does not equal the summation of the prevalence of intra- and extradural UIAs because some participants had both intra- and extradural UIAs.

Table 5: Comparison of the four population-based studies on prevalence of unruptured intracranial aneurysms (UIAs) according to the number of participants, age tange and age mean, magnetic resonance imaging (MRI) field strength, sequence and postprocessing techniques, definition of UIAs and prevalence of UIAs.

Year	Authors	Study	N	Age, range, (years)	Age, mean, (years)	MRI field strength	MRI sequence for detevtion of UIAs	Post-processing techniques	Including extradural aneurysms	Aneurysm size, treshold	Prevalence of UIAs
2013	Müller et al.[5]	HUNT	1006	50-65	58.5	1.5T	3D-TOF-MRA	MIP, MPR	unknown	unknown	1.9%
2016	Bos et al.[6]	Rotterdam	5800	≥45	64.9	1.5T	PDW	MPR	unknown	unknown	2.3%
2013	Li et al.[7]	Shanghai	4813	35-75	52.1	3.0T	3D-TOF-MRA	VR, MIP, MPR	yes	≥2 mm	7.0%
2022	Johnsen et al.	Tromsø	1862	40-84	63.8	3.0T	3D-TOF-MRA	VR, MIP, MPR	no	≥2 mm	6.6%

3D-TOF-MRA; 3-dimentional time-of-flight magnetic resonance angiography, MIP; maximum intensity projection, VR; volume-rendered, PDW; proton density-weighted, MPR; multiplanar reconstruction