Radiological monitoring of incidental abdominal aortic aneurysms

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ABSTRACT:

Background: Incidental abdominal aortic aneurysms (AAAs) are identified when the abdomen is imaged for other reasons. No population-based studies exist to measure the completeness of incidental AAA radiographic monitoring.

Methods: A cohort of incidental AAAs (previously unidentified aortic enlargement exceeding 3cm found on imaging study done for other reason) was linked to population-based data. Patients were followed to elective AAA repair, AAA rupture, death, or 31 March 2009. We used evidence-based monitoring guidelines to calculate the proportion of observation time during which incidental AAAs were incompletely monitored. We used negative binomial regression to determine the association of patient factors with this outcome.

Results: We identified 191 incidental AAAs between 1996 and 2004 (mean diameter of 3.5 cm [range 3.0-5.3], median follow-up 4.4 years [range 0.6-12.7]). 56 patients (29.3%) had no radiographic monitoring of their aneurysm. Overall, patients spent one fifth of their time with incomplete AAA monitoring (median 19.4%, IQR 0.3%-44%). Factors independently associated with incomplete monitoring included increased patient age (relative change in time with incomplete monitoring [RR] 1.27 [1.10-1.47] per decade), larger AAA size (RR 1.65 [1.38-2.01] per 10mm increase), and having the AAA detected when the patient was in the hospital or emergency (RR 1.34 [1.00-1.79]). Patient comorbidity was not associated with AAA monitoring.

Conclusion: Incidental AAA radiographic monitoring is incomplete with almost a third of patients having none. Incomplete monitoring does not appear to be related to patient comorbidity.

INTRODUCTION:

Incidental findings during radiological examinations are unexpected abnormalities that are identified when tests are conducted for other reasons. They are very common, occurring in 5% to 20% of radiological tests.[1-5] The health benefit that patients derive from identifying most incidental findings is questionable.[1] However, detecting an incidental abdominal aortic aneurysm (AAA) can greatly benefit a patient as long as it is monitored and is repaired – in appropriate candidates - when enlarged.

Incidental AAAs are common. Gordon et. al. found incidental AAAs in 2.2% of computer tomographic (CT) scans.[6] At our institution, 1% of all abdominal ultrasounds, CTs, and magnetic resonance imagings identified an incidental AAA.[7] The high frequency of such abdominal imaging studies in most hospitals will result in the identification of many incidental AAAs. It is therefore important to know if they are being managed appropriately.

Since the natural history of AAAs involves progressive enlargement, smaller AAAs are monitored with serial radiographic imaging to determine when surgical repair should be considered in appropriate candidates. Incidental AAAs might be incompletely monitored since they are frequently not documented by physicians [6] or communicated to the primary care physician.[7] However, no population-based analysis of incidental AAA monitoring has ever been done.

In this study, we used population-based data to measure the completeness of incidental AAA monitoring. To infer why incidental AAAs might be incompletely monitored, we measured the association of incidental monitoring with patient factors.

METHODS:

This study was approved by the Ottawa Hospital Research Ethics Board.

Datasets Used for the Study:

This study used several population-based administrative datasets in Ontario, Canada, which has a publically-funded health care system. The Ontario Health Insurance Plan (OHIP) dataset records claims for ~95% of physician services and all radiographic studies. The Discharge Abstract Database (DAD) records information about all hospitalizations. The National Ambulatory Care Reporting System (NACRS) records information about all emergency room visits. The Registered Patients Database (RPDB) records the birth and (where applicable) death date of all Ontarians. The Ontario Chronic Care Patient System (OCCPS) records all patients staying in Ontario registered long term care facilities up to 2006 (after which it is replaced by the Chronic Care Reporting System). The Ontario Drug Benefits (ODB) database records all prescriptions for patients exceeding 65 years of age and those on social assistance. These datasets were linked using common encrypted patient identifiers. The database codes used for the study are listed in Appendix A.

Study Cohort:

This study included patients who underwent abdominal imaging at The Ottawa Hospital (TOH) between 1996 and 2008 (Figure 1). We identified imaging studies using the Ottawa Hospital Data Warehouse, a database containing patient and encounter information for the Ottawa Hospital. We electronically screened the text reports of a 25% simple random sample of 311 066 abdominal computerized tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI) examinations using a validated text analysis algorithm.[7] 9511 "screen-positive" reports were manually reviewed to identify all incidental AAAs. These were defined as abnormal dilation of the abdominal aorta with: a maximal diameter of or exceeding 30 mm; the imaging study not getting done for symptoms or signs of AAA; no mention of any previous AAA in the report; and the AAA showing no signs of leaking or rupture. Patients were also excluded if their AAA diameter exceeded 55 mm (since these people are repaired rather than monitored) or if the AAA was surgically repaired immediately after it was identified.

This dataset was linked to OHIP (Appendix A) to identify all abdominal imagings done on patients prior to the date the AAA was identified. Knowing the AAA diameter and the date it was identified, we used the AAA growth equation from Brady *et. al.*[8;9] to estimate when prior imaging would have identified an AAA that exceeded 30 mm (Appendix B). People with prior abdominal imaging that would have identified an AAA exceeding 30 mm were excluded from the study (since their AAAs were not truly identified incidentally). Finally, patients whose total observation time (defined below) was less than the time to the first recommended monitoring scan (Appendix C) were also excluded.

Data Collection:

From the abdominal imaging report, we abstracted the AAA's size and location. From our hospital's information system we determined the patient's age, sex, and location when the AAA was identified (i.e. community, emergency department, or hospital). From the medical record of hospitalized patients, we determined functional and prognostic status using the Walter Index[10] (a validated measure predicting the 1 year mortality risk in patients discharged from hospital) and whether a discharge summary of the hospitalization sent to the patient's family physician mentioned the AAA.

We linked to OHIP to identify all abdominal US, CT, and MRI studies conducted on the cohort during their observation period (Appendix A). We assumed that all such studies examined the AAA regardless of its indication. We used data from Brady et. al.[8;9] to estimate AAA diameter at any time during patient follow-up (Appendix B). This diameter was compared to Canadian Cardiovascular Society guidelines[11] to determine the recommended time to next AAA monitoring imaging study (Appendix C). These guidelines are essentially identical to those recommended by the American College of Cardiology[12] and data-based recommendations from Brady.[8] The monitoring frequency in these guidelines has been shown by Brady et. al. to reduce the risk of unmonitored AAA growth beyond 55 mm to 1%.[9]

Outcomes:

Two outcomes were used to quantify incomplete monitoring. First, people who had no abdominal imaging during their observation time were classified with no monitoring. Second, we calculated the percent of time with incomplete monitoring (defined as the total number of years without recommended radiographic monitoring divided by years of observation). **Total years without recommended radiographic monitoring** was quantified based on guidelines for appropriate frequency of AAA monitoring (Appendix C). Using the AAA diameter, this schedule is used to define within what time repeat radiologic AAA monitoring is required. When abdominal imaging was done, we entered the baseline AAA diameter and the time to the repeat imaging test into a model to estimate the AAA size at the follow-up test (Appendix B). This process was used through the patient's observation period to calculate the total number of years without recommended radiographic monitoring (see Appendix D for an illustration). **Patient observation** started when the incidental AAA was identified and ended at the earliest of: elective AAA repair (identified in DAD, Appendix A); admission to emergency department or hospital for ruptured AAA (identified in NACRS and DAD, respectively; Appendix A); all-cause death (identified in RPDB); or 31 March 2009 (the final date at which all databases were current).

Potential Confounders:

We linked to population-based datasets to capture six measures of patient comorbidity that could influence whether or not someone would be a candidate for elective AAA repair and, therefore, AAA monitoring. Disease non-specific measures included: the number of emergency room admissions in year prior to identification of the incidental AAA (captured by linking to NACRS and OHIP); the number of emergent hospitalizations in year prior to baseline (from DAD); the nursing home status at baseline (from CCRS); and the number of different drugs prescribed in year prior to baseline (from ODB). The latter confounder was complete for all patients over the age of 65 (81.2% of cohort) and those whose medications are paid through social assistance (unknown proportion of cohort). Disease-specific comorbidity measures included: presence of diabetes captured by linkage to the Ontario Diabetes Database (a population-based registry of diabetic Ontarians); and acute coronary syndrome determined by linking to the Ontario Myocardial Infarction Database (a population-based registry of patients with myocardial infarction).[13]

Analysis:

The independent association of baseline factors with whether or not people underwent any radiographic monitoring was determined using multivariate binary logistic regression. For the percent of time patients had incomplete monitoring, we used negative binomial regression (in which the outcome variable was the number of days the AAA was incompletely monitored and the offset variable was the total number of days of observation). Given the small sample size, we only considered for inclusion those variables whose univariate association with each outcome was less than 0.2. Both models used backward variable selection with significance level of 0.1 for variable retention.

We conducted several sensitivity analyses. First, we repeated the analysis adding date of last contact with the health care system as a censoring variable (along with date of death, AAA rupture, AAA repair, or 31 March 2009). The date of last contact is the date of the last record for the patient in OHIP, ODB, DAD, or NACRS. Second, we performed a formal chart review of patients who were hospitalized when the AAA was identified to determine whether detailed comorbidity measures influenced AAA monitoring. We measured comorbidity using the validated Walter index[14] and determined whether physicians documented reasons why patients would not be candidates for monitoring. Finally, we also determined whether hospital physicians communicated the AAA to the patient's family physician with a discharge summary.

RESULTS:

Between January 1996 and September 2008, the Ottawa Hospital conducted 311 006 abdominal CT, US, and MRIs (Figure 1). 79 121 reports (25%) were randomly selected for screening of which 9511 were 'screen positive', 812 indicated an incidental AAA (based on information given in the report), 775 could be linked to population-based databases, and 470 had no previous abdominal imaging that would have identified the AAA. Of these, 289 were excluded because the AAA was repaired - or the patient died – during the index admission (n=41), the AAA diameter exceeded 55 mm (n=35), or their observation period did not extend beyond their 1st recommended monitoring scan (Appendix C, n=203).

This left a cohort of 191 patients with an incidental AAA that required monitoring (Table 1). These patients were elderly (mean age 73) and mostly male (74.3%) with a quarter having diabetes and 10% had a previous myocardial infarction. AAAs were small (mean diameter 38 mm) and most patients were in the community when the AAA was identified.

Incidental AAA Monitoring

56 patients (29.3%) had no monitoring of their AAA (Table 1). 35 (18% of the entire cohort) of these patients were seemingly healthy (70 years old or less; not in a nursing home; and no emergency room visits or hospitalizations in the previous year). At the univariate level, radiological monitoring was less likely in the elderly, women, patients with greater number of hospitalizations or medications, those from a nursing home, and those with wider AAAs at baseline (Table 1). However, when these variables were included in a logistic regression model, only patient age remained independently associated with whether or not patients had *any* radiological monitoring. The adjusted odds of undergoing radiological monitoring dropped by half when patient age increased by a decade (adjusted odds ratio 0.485, 95% CI 0.331-0.710).

Patients spent a considerable amount of their observation time without proper monitoring of their AAA. Overall, patients spent almost a fifth of their time with incomplete monitoring (median 19.4%, IQR 0.3-44%). 42 patients (22.0%) spent the majority (i.e. more than 50%) of their time with incomplete monitoring. Time to first monitoring scan appeared to be independent of the baseline size of the AAA (Table 2). In the univariate analysis, incomplete monitoring was most strongly associated with patient age and AAA diameter (Table 3). In the multivariate model, monitoring was more incomplete in the elderly, those with larger AAAs, and those whose AAA was identified in the emergency room or the hospital (Table 3). None of the comorbidity measures were associated with AAA monitoring.

Figure 2 displays the extent that factors from the multivariate model influenced the percent of time with incomplete monitoring. These plots show the important effect that both patient location when the AAA was identified and baseline AAA diameter had on monitoring. Controlling for the other variables in the model, patients whose AAA was identified in the emergency department or the hospital spent 20.2% (95%CI 14.1, 28.9) of their time with incomplete monitoring (compared to 16.3% [95%CI 12.0-22.1] in those from the community). Notably, patients whose AAA diameter exceeded 45mm also had alarmingly poor monitoring rates, spending 41.5% (95%CI 27.1-63.4) of their time with incomplete monitoring (compared to 16.3% [12.0-22.1] in those whose diameter was less than 35mm).

Sensitivity Analyses:

Censoring patient observation at date of last contact with the health care system changed observation time for only 14 people (7.3%) in the cohort (mean decrease in observation time, 3.2 months). The median time spent with incomplete monitoring did not change significantly (17.9% [IQR 0-41] vs. 19.4 [IQR 0.3-44]). Parameter estimates of the regression model did not change significantly but the p-value for patient location increased to 0.18.

37 people were in the hospital when their AAA was identified. By reviewing their chart, more information was collected regarding their baseline comorbidity and the communication of their incidental AAA. A Walter score of 4 (which is asscociated with a risk of death in 1 year that exceeds 34%[14]) was found in 14 patients (37.8%) and a discharge summary identifying the AAA was sent to the family physician in 7 patients (18.9%). Neither the Walter score (p=0.81) nor the discharge summary communicating the AAA (p=0.87) was significantly associated with percent of time with incomplete monitoring.

DISCUSSION:

To our knowledge, this is the first examination of incidental AAA radiographic monitoring using population-based data. Our results show that incidental AAA monitoring is incomplete. Almost one third of people undergo no monitoring with most of these people seemingly healthy. People spent almost one fifth of their time with incomplete monitoring. Incomplete monitoring does not appear to be related to patient comorbidity. Further study is required to determine whether incomplete monitoring of incidental AAA increases the risk of poor patient outcomes.

Patients who are very ill or who have a short life expectancy do not require radiographic monitoring of their AAA. However, we do not believe that this explains the incomplete monitoring identified in this study. First, 35 of the 56 people with no monitoring (62.5%) appeared healthy (less than 70 years old, not in a nursing home, and having no emergency room visits or hospitalizations in the year prior to their AAA identification). Second, the only comorbidity marker that was associated with incomplete monitoring was patient age. All other factors indicative of patient illness were not associated with AAA monitoring.

There are two potential explanations for the lack of association between monitoring completeness and patient comorbidity. First, it is possible that we have incompletely captured comorbidity in our study given that we used population-based administrative data – which may lack clinical details required to completely define patient sickness[15] - to quantify patient comorbidity. We don't think, however, that this completely explains our finding because, apart from age, none of the large selection of comorbidity measures in our study influence monitoring completeness. In addition, our sensitivity analysis in the hospitalized patients showed no association between monitoring completeness and the Walter Index[14] – a validated index shown to predict risk of death.

The second – and, we think, more likely – potential reason for the lack of association between AAA monitoring and patient comorbidity stems from its cause. If these incidental findings are being randomly dropped by physicians, comorbidity will not be associated with monitoring completeness. Our observation that incidental AAAs identified in the ED or the hospital had more incomplete monitoring supports this hypothesis. Such AAAs are identified by physicians – i.e. emergency room physicians and hospitalists – who frequently do not see patients after the acute treatment episode. If these physicians fail to communicate the incidental AAA to the patient or their regular physician - which occurred in 74% of patients in our original study[7] – then incomplete monitoring will not be associated with patient comorbidity. Further work is required to determine what factors result in incomplete monitoring of incidental AAAs.

Our study had both a binomial outcome (proportion of patients with no repeat imaging) and a rate (proportion of follow-up time with incomplete monitoring). Results for the former outcome (almost one third of patients have no follow-up monitoring) paints a more concerning picture than that for the latter (almost one fifth of patient time was spent with incomplete monitoring). This distinction occurs because the latter outcome considers the index scan itself as AAA monitoring (with a duration that varies varying by the diameter of the index AAA based on Appendix C). However, since almost one third of people get *no* follow-up monitoring, counting the index AAA as monitoring could be interpreted as generous for a large component of people whose abnormalities are seemingly being dropped.

Several aspects of our study are notable. First, we are confident that our study solely included newly identified incidental AAAs since we used population-based data to exclude all AAAs that might have been identified on previous abdominal imaging. We may have excluded some incidental AAAs with this approach (since the act of imaging does not necessarily mean pathology was recognized). We focused our analysis on a restrictive, truly incidental subset of patients because we felt this would be the most realistic evaluation of the clinical phenomenon we are studying – specifically, the failure to act on incidental findings. As a result of our approach, our study should not be used to estimate the burden of unrecognized AAAs in our population. Second, we were struck by the fact that larger AAAs were not being monitored more frequently than smaller AAAs. In fact, those with the smallest AAAs had the most frequent monitoring (Table 2). This finding could indicate a lack of familiarity with AAA growth and monitoring guidelines (Appendix C). It could also indicate that some of the incidental AAAs have a haphazard follow-up. Finally, we are uncertain what effect incomplete monitoring would have on patient outcomes such as rupture and sudden death. The risk of these outcomes increases dramatically when AAA diameter exceeds 55 mm. Since the recommended monitoring schedules (Appendix C) were created to decrease the risk that AAAs grow undetected into this size range, one would expect that incomplete monitoring of these AAAs would increase the risk of experiencing rupture. Further analyses are required to determine if this is indeed the case.

Several interventions could improve the monitoring of incidentally identified AAAs. Radiologists could directly contact ordering physician about the identification of the seemingly incidental AAA. A copy of the report identifying the incidental AAA could be sent to the patient's family physician along with recommendations for repeat abdominal imaging frequency. Patients without a family physician could be automatically booked for follow up abdominal imaging within the recommended time-span (Appendix C) or referred to vascular surgeons. Finally, a letter could be sent to the patient explaining the incidental AAA, its implications, and recommended actions. Computer-based algorithms - similar to those that we have developed for other radiographic abnormalities[16] - could be developed to automate these procedures to ensure the feasibility of these enhancements.

Contributions and competing interests:

All authors contributed substantially to conception and design, or acquisition of data, or analysis and interpretation of data. All authors drafted the article or revised it critically for important intellectual content and all gave final approval of the version to be published.

The authors have no competing interests regarding this paper.

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Table 1: Description of study cohort overall and by monitoring status

	Overall	**No Monitoring**	**Some Monitoring**	**Univariate P-value***
	N=191	**N=56 (29.3%)**	**N=135 (70.7%)**	
Demographic				
Mean age (95% CI)	73.3 (71.9, 74.6)	77.3 (75.0, 79.7)	71.6 (70.1, 73.1)	<.001
Female	49 (25.7%)	19 (33.9%)	30 (22.2%)	0.092
TOH Campus - Civic	64 (33.5%)	21 (37.5%)	43 (31.9%)	0.597
- General	104 (54.5%)	27 (48.2%)	77 (57.0%)	
- Other	23 (12.0%)	8 (14.3%)	15 (11.1%)	
Patient Comorbidities				
Median number ED visits in previous year (IQR)	0 (0-1)	0 (0-1)	0 (0-1)	0.881
Mean # hospitalizations in previous year (95% CI)	0.51 (0.39, 0.63)	0.80 (0.53, 1.07)	0.39 (0.27, 0.51)	0.002
Median # drugs prescribed in previous year (IQR)	6 (1-10)	7 (3-11)	5 (0-10)	0.066
From nursing home	2 (1.0%)	2 (3.6%)	0 (0.0%)	0.027
Diabetes	46 (24.1%)	14 (25.0%)	32 (23.7%)	0.849
Previous MI	19 (9.9%)	4 (7.1%)	15 (11.1%)	0.404
Aneurysm Information				
Patient location when AAA identified - community	135 (70.7%)	39 (69.6%)	96 (71.1%)	0.473
- ED or hospital	56 (29.3%)	17 (30.4%)	39 (38.9%)	
Infrarenal AAA	170 (89.0%)	50 (89.3%)	120 (88.9%)	0.936
Mean AAA diameter, mm (95% CI)	37.6 (36.6, 38.6)	38.6 (36.8, 40.5)	37.1 (35.9, 38.3)	0.18

* Does not account the for influence of other variables in table.
(ED = Emergency Department; IQR = interquartile range; CI = confidence interval).

Table 2: Influence of baseline AAA diameter on time to first monitoring scan.

Size (mm)	N	Mean Number of Years to 1st Scan (95% CI)	Recommended Number of Years to 1st Scan*	N (%) people meeting recommended time to 1st scan
<35	82	4.9 (3.3-6.5)	3	54 (65.8%)
35-39	37	7.1 (4.3-9.9)	2	20 (54.0%)
40-44	36	6.1 (3.7-8.4)	1	15 (41.7%)
45+	36	6.6 (3.8-9.4)	0.5	15 (41.7%)

* based on Canadian Cardiovascular Society recommendations.

Table 3: Association of baseline patient factors with proportion of time that AAA was incompletely monitored.

	Unadjusted				Adjusted			
Factor	**Relative Rate**	**-95**	**+95**	**P-value**	**Relative Rate**	**-95**	**+95**	**P-value**
Age (10 year increase)	1.29	1.10	1.52	0.002	1.27	1.10	1.47	0.001
Female	1.27	0.90	1.80	0.176	-	-	-	-
Median number ED visits in previous year	1.10	0.79	1.52	0.584	-	-	-	-
Mean # hospitalizations in previous year	1.23	0.89	1.71	0.207	-	-	-	-
# drugs prescribed in previous year	1.00	0.98	1.03	0.855	-	-	-	-
From nursing home	2.75	0.90	8.41	0.076	-	-	-	-
Diabetes	0.92	0.63	1.33	0.652	-	-	-	-
Previous MI	0.67	0.36	1.23	0.202	-	-	-	-
Patient location (Hospital or ED vs. community)	1.56	1.13	2.16	0.007	1.34	1.00	1.79	0.05
Infrarenal AAA	1.44	0.85	2.44	0.175	-	-	-	-
AAA diameter (10 mm increase)	1.75	1.43	2.14	<.0001	1.65	1.38	2.01	<.0001

The relative rate presents the relative proportion of time that a person with the factor spends with incomplete monitoring (e.g. a relative rate of 1.5 indicates that the proportion of time with incomplete monitoring was 50% higher in those with vs. those without the factor).

Figure 1. Creation of study cohort

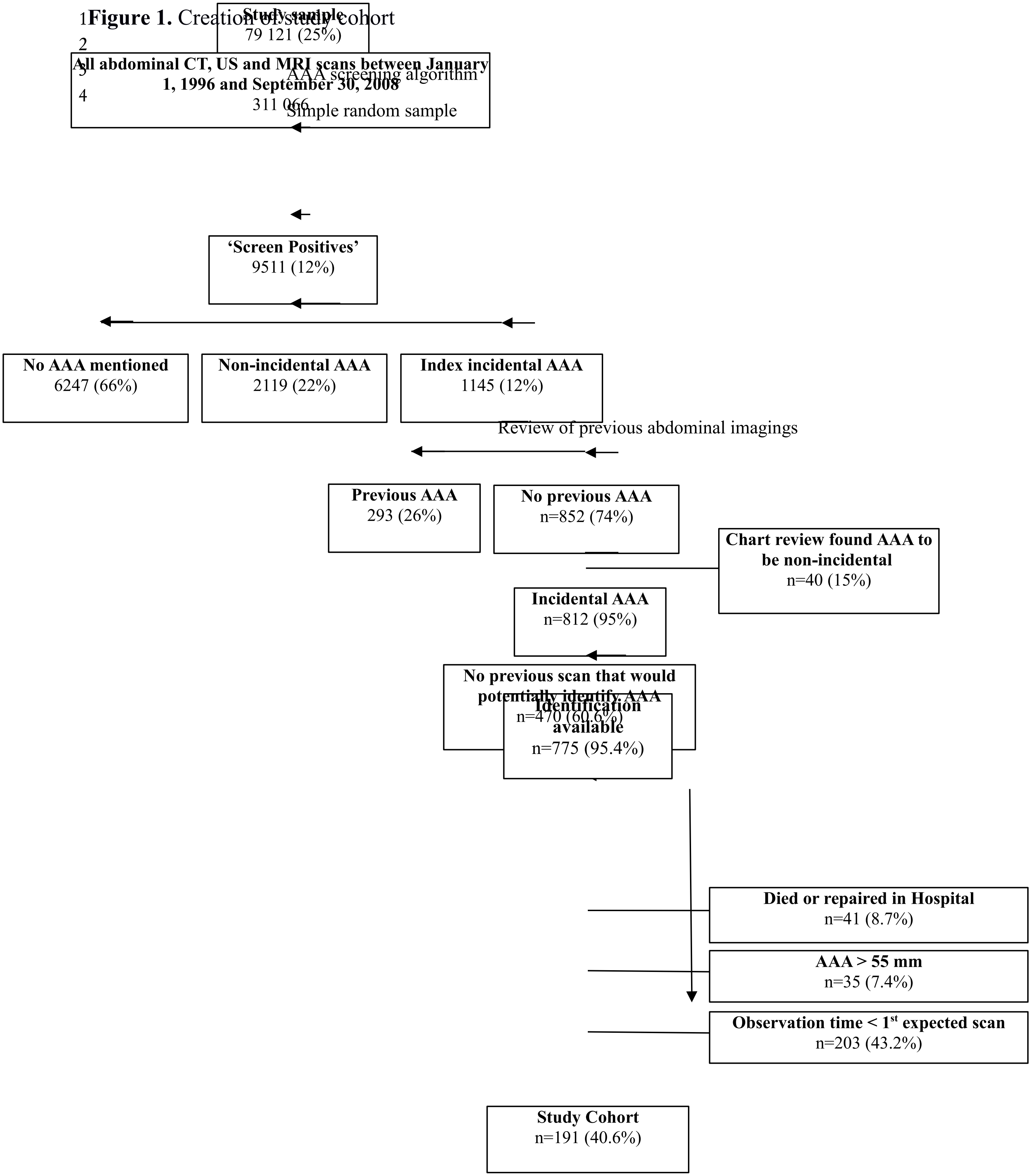
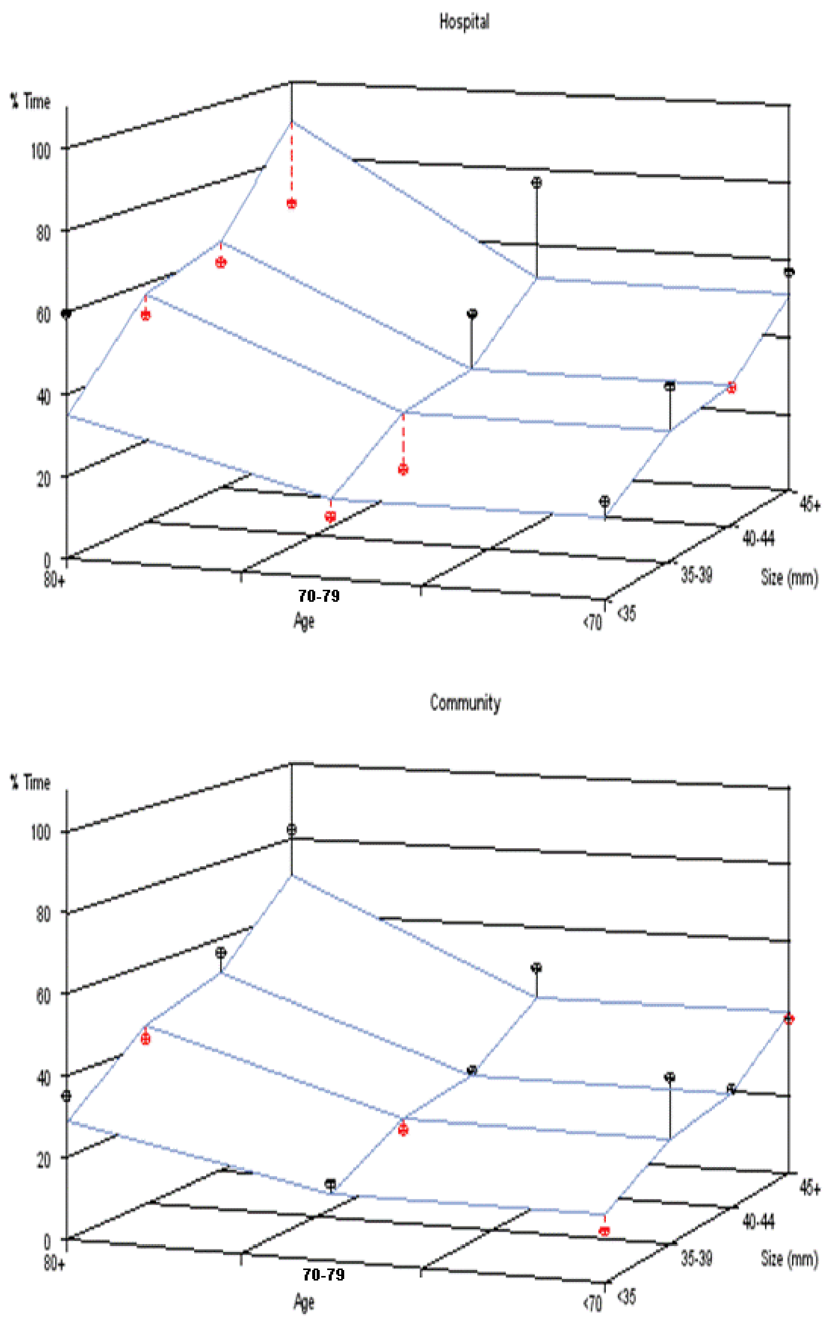


Figure 2: Independent association of important baseline factors on proportion of time AAA adequately monitored.



This figure presents the relationship between patient age (Age), AAA diameter (Size), and percent time without appropriate radiological monitoring (% Time) by patient location when the AAA was identified (Community vs. Hospital). The model presented in Table 2 was used to generate the expected values (presented as the plane in each plot).

Observed values that exceed expected values are presented in black; those that are less than expected values are presented in red.

1**Appendix A:** Database codes used for this study.

Entity	Sub	Dataset	Pre-2002	2002+
Ruptured AAA		CIHI-DAD	441.1	I71.0
			441.3	I71.1
			441.5	I71.3
				I71.5
				I71.8
Abdominal Imaging	CT	OHIP	X409	X409
			X410	X410
			X126	X126
	MRI	OHIP	X451	X451
			X455	X455
	US	OHIP	J135	J135
			J435	J435
			J128	J128
			J428	J428
AAA Repair			38.34	1ID76MU-XXA/K/N/Q
			38.36	1ID76MV-XXA/K/N/Q
			38.44	1ID76MX-XXA/K/N/Q
			38.45	1ID76MY-XXA/K/N/Q
			38.46	1ID76MZ-XXA/K/N/Q
			38.64	1ID80LA-XXA/K/N/Q
			39.25	1ID80QF-XXA/K/N/Q
			39.26	1KA50GQ-BD/OA
			39.29	1KA80GQ-NRN
			39.52	1KA76MZ-XXA/K/N/Q
			39.71	1KA76NM-XXA/K/N/Q
				1KA80LA-XX/A/K/N/Q
				1KE50GQ-BD/BF/OA
				1KE50LA-BD/BF

2

Appendix B: Using baseline AAA diameter to estimate aneurysm diameter at subsequent abdominal imaging.

Brady [9] determined the following quadratic equation to model AAA growth over time:

(A) AAA diameter (mm) = $0.11*(\text{years from baseline})^2 + 2.3*(\text{years from baseline}) + 42.9$

We used this equation to estimate AAA diameter at any time during their observation using the following steps:

1. *Determine the number of years it would take from baseline for the patient's AAA to grow to 42.9mm:* Brady's quadratic equation models the growth of AAA whose diameter at baseline is 42.9mm. We rearranged this equation to determine the number of years it would take for the patient's AAA to grow to 42.9mm:

(B) $$\text{Years required for AAA to grow from baseline diameter to 42.9mm} = \frac{-2.3 + \sqrt{(-13.59+0.44*\text{baseline AAA diameter})}}{0.22}$$

   Note that this will return a negative number if the baseline AAA diameter exceeds 42.9 mm.

2. *Determine the number of years between when the incidental AAA was identified and the subsequent scan.*

3. *Add the years required for AAA to grow from baseline diameter to 42.9mm (from 1) to number of years from baseline to subsequent scan (from 2).*

4. *Calculate the estimated AAA diameter at the subsequent scan by solving equation A using the value from 3 as the 'years from baseline'.*

For example, consider a patient whose AAA was 40mm at baseline. Solving equation **B** with a baseline AAA diameter of 40 returns -1.35 (indicating that it would take this AAA 1.35 years to grow from 40 mm to 49.2 mm). If the subsequent scan occurred 15 months after the incidental scan, we would add (15/12) and -1.35 to get -0.10 and then substitute this value into equation **A** to get the AAA diameter at the subsequent scan:

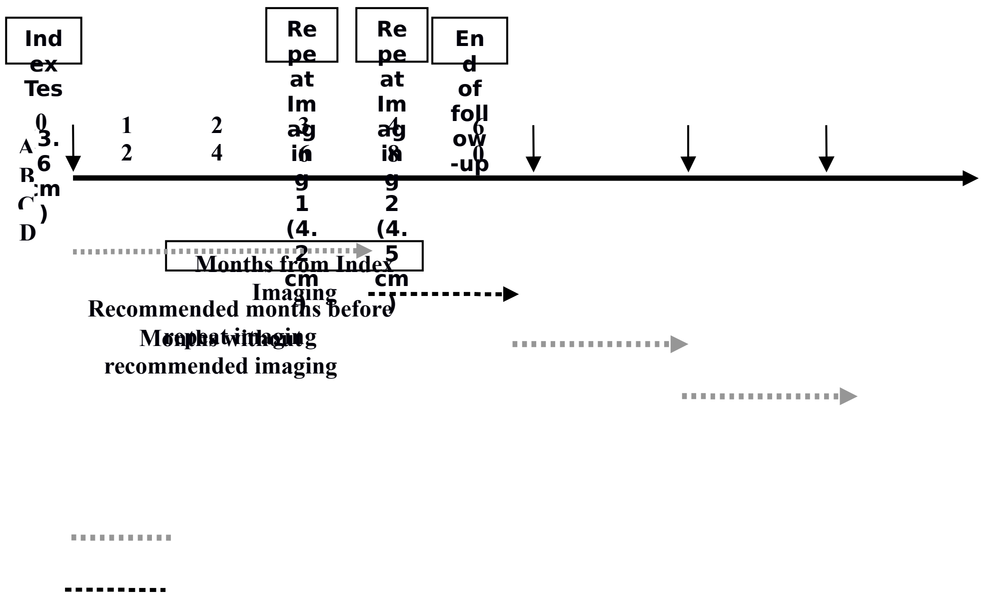
$$0.11(-0.10^2) + 2.3(-0.10) + 42.9 = 42.7\text{mm}.$$

Therefore, an AAA that was 40 mm would be estimated to have a diameter of 42.7mm in 15 months.

Appendix C: Frequency of AAA Imaging Required to Reduce Risk of Growth Beyond 5.5cm to < 1% [8].

Aneurysm Diameter	***Imaging Frequency Recommended by Brady[8]***	***Imaging Frequency Recommended by Canadian Cardiovascular Society*[11]***	***Imaging Frequency Recommended by American College of Cardiology / American Heart Association[12]***
≤3.5 cm	Every 36 months	Every 36 months	Every 24-36 months
3.6-4.0 cm	Every 24 months	Every 24 months	
4.1-4.5 cm	Every 12 months	Every 12 months	Every 6 months
4.6-5.0 cm	Every 3 months	Every 6 months + referral to Vascular Surgery	
>5.0 cm	Every 2 months		Referral for repair

Appendix D: Quantifying number of years without recommended radiographic AAA monitoring



The figure illustrates how we quantified the total amount of time a person spent without radiographic monitoring of their AAA. The person above had an incidental AAA with a diameter of 3.6 cm identified at time 0. The table in Appendix B indicates that this person should have had a repeat imaging done within 24 months (Line A). However, the first repeat imaging was not done until 36 months. This person therefore accumulated 12 months without recommended abdominal imaging (Line B). To estimate the size of the AAA at 36 months, we used the methods in Appendix B. The estimated AAA diameter at 36 months is 4.2 cm. Applying this estimated diameter to the schedule in Appendix C indicates within what time the next imaging was required (in this case, 12 months - Line C). For this person, a second repeat imaging was done within the recommended time period. Repeating these steps concludes that the third repeat imaging should occur by month 60 (Line D).