Radiographic monitoring of incidental abdominal aortic aneurysms: a retrospective population-based cohort study

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ABSTRACT

Background: An abdominal aortic aneurysm (AAA) that is identified when the abdomen is imaged for some other reason is known as an incidental AAA. No population-based studies have assessed the management of incidental AAAs. The objective of this study was to measure the completeness of radiographic monitoring of incidental AAAs by means of a population-based analysis.

Methods: We linked a cohort of patients with incidental AAA (defined as a previously unidentified aortic enlargement exceeding 30 mm in diameter found in an imaging study performed for another reason) to various population-based databases. We followed the patients to elective repair or rupture of the aneurysm, death or 31 Mar. 2009. We used evidence-based monitoring guidelines to calculate the proportion of observation time during which each incidental AAA was incompletely monitored. We used negative binomial regression to determine the association of patient-related factors with this outcome.

Results: For the period between January 1996 and September 2008, we identified 191 patients with incidental AAA (mean diameter 37.6 mm, 95% confidence interval [CI] 36.6–38.6 mm; median follow-up 4.4 [range 0.6–12.7] years). Fifty-six of these patients (29.3%) had no radiographic monitoring of the aneurysm. Overall, patients spent one-fifth of their time with incomplete monitoring of the AAA (median 19.4%, interquartile range 0.3%–44.0%). Factors independently associated with incomplete monitoring included older age (relative rate [change in proportion of time with incomplete monitoring] [RR] 1.27, 95% CI 1.10–1.47, per decade), larger size (RR 1.65, 95% CI 1.38–2.01, per 10-mm increase) and detection of the aneurysm while the patient was in hospital or the emergency department (RR 1.34, 95% CI 1.00–1.79). Comorbidities were not associated with monitoring.

Interpretation: Radiographic monitoring of incidental AAAs was incomplete, and almost one-third of patients underwent no monitoring at all. Incomplete monitoring did not appear to be related to patients' comorbidity.

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Incidental findings during radiographic examinations are unexpected abnormalities that are identified when tests are conducted for other reasons. Such findings are common, being identified in 5% to 20% of radiographic tests.[1–5] In most cases, the health benefit that patients derive from incidental findings is questionable.[1] However, detecting an incidental abdominal aortic aneurysm (AAA) can be of great benefit to the patient, provided that the aneurysm is monitored and is repaired—if the patient is a suitable candidate for surgery—if it becomes enlarged.

Incidental AAAs are common. Gordon and colleagues[6] found incidental AAAs in 2.2% of computed tomography (CT) scans. At our institution, 1% of all abdominal imaging by CT and magnetic resonance imaging (MRI) revealed an incidental AAA.[7] The high frequency of 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. The natural history of AAAs involves progressive enlargement, so smaller AAAs are monitored with serial radiographic imaging to determine when surgical repair should be considered for patients suitable for such surgery. Incidental AAAs might be incompletely monitored because many of them are not documented by physicians[6] or their existence is not communicated to the primary care physician.[7]

In this study, our primary objectives were to use population-based data to measure the completeness of monitoring of incidental AAAs and to determine the association of incidental monitoring with patient factors to identify potential reasons why incidental AAAs might be incompletely monitored.

Methods

This retrospective population-based cohort study, which involved the use of administrative databases, was approved by the Ottawa Hospital Research Ethics Board.

Data sets. For this study, we used several population-based administrative data sets available in Ontario, Canada, which has a publicly funded health care system. The Ontario Health Insurance Plan (OHIP) data set records claims for about 95% of physician services and all radiographic studies conducted in the province. The Discharge Abstract Database (DAD) of the Canadian Institute for Health Information records information about all hospital admissions. The National Ambulatory Care Reporting System (NACRS) records information about all emergency department visits. The provincial Registered Persons Database (RPDB) records the date of birth and (where applicable) the date of death of all Ontarians. The Ontario Chronic Care Patient System (OCCPS) recorded all patients staying in registered long-term care facilities in Ontario up to 2006, after which it was replaced by the Chronic Care Reporting System (CCRS). The database of the Ontario Drug Benefit (ODB) Program records all prescriptions for patients aged 65 years or older and those receiving social assistance. We linked these data sets using the same encrypted patient identifiers. The database codes used for the study are listed in Appendix 1 (available online). All of the databases were complete (and therefore our observations of patients were complete) to 31 Mar. 2009.

Study cohort. This study took place at The Ottawa Hospital in Ottawa, Ontario, Canada. All patients who underwent abdominal imaging at this institution between January 1996 and September 2008 were eligible for inclusion (Fig. 1). We identified abdominal CT, ultrasonography (US) and MRI examinations through the Ottawa Hospital Data Warehouse, a database containing patient and encounter information for The Ottawa Hospital. We used a validated text-analysis algorithm to electronically screen the text reports of the imaging studies.[7] Our goal was to identify 1000 incidental AAAs, before invoking other exclusion criteria related to previous out-of-hospital imaging and follow-up time. Pilot data obtained with the text-screening algorithm showed that between 10% and 15% of screening-positive reports involved truly incidental AAAs. Therefore, we needed to identify up to 10 000 screening-positive reports to generate our sample. A total of 311 066 imaging studies were available, and we electronically screened a 25% simple random sample created with computer-generated random numbers (searching the text of approximately 79 000 records to generate about 9500 screening-positive reports), because reviewing the entire sample manually (i.e., searching the text of 311 000 studies to generate about 36 000 screening-positive reports) would have been prohibitive.

We manually reviewed the screening-positive reports identified by the text-screening algorithm to identify all incidental AAAs. An incidental AAA was defined as abnormal dilatation of the abdominal aorta (maximal diameter 30 mm or more) in a patient who underwent imaging for a reason other than symptoms or signs of AAA, with no mention of any previous AAA in the report and no signs of leaking or rupture of the AAA. Patients were excluded if the AAA diameter exceeded 55 mm (because these large lesions are repaired rather than being monitored) or if the AAA was repaired surgically immediately after it was identified (even if smaller than 55 mm diameter).

We linked the data set of patients with incidental AAA to the OHIP database (using the codes listed in Appendix 1) to identify all abdominal imaging performed for these patients before the date when the AAA was identified. Knowing the diameter of the aneurysm and the date on which it was identified, we used the AAA growth equation of Brady and colleagues[8,9] to estimate when prior imaging would have identified an AAA that exceeded 30 mm (Appendix 2, available online). We excluded patients with prior abdominal imaging that would have identified an AAA exceeding 30 mm, since identification of their AAAs was not truly incidental. We also excluded patients with a total observation time (defined below) less than the time to the first recommended monitoring scan (Appendix 3, available online).

Data collection. At The Ottawa Hospital, a copy of the imaging report is routinely sent to the ordering physician, as well as to any other physician specified on the requisition. We reviewed each patient's abdominal imaging reports to identify the size and location of the AAA. From the 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 records of hospital inpatients, we determined functional and prognostic status by means of the Walter index,[10] a validated measure predicting the 1-year mortality risk for patients discharged from hospital, and whether the AAA was mentioned in a discharge summary of the hospital stay sent to the patient's family physician.

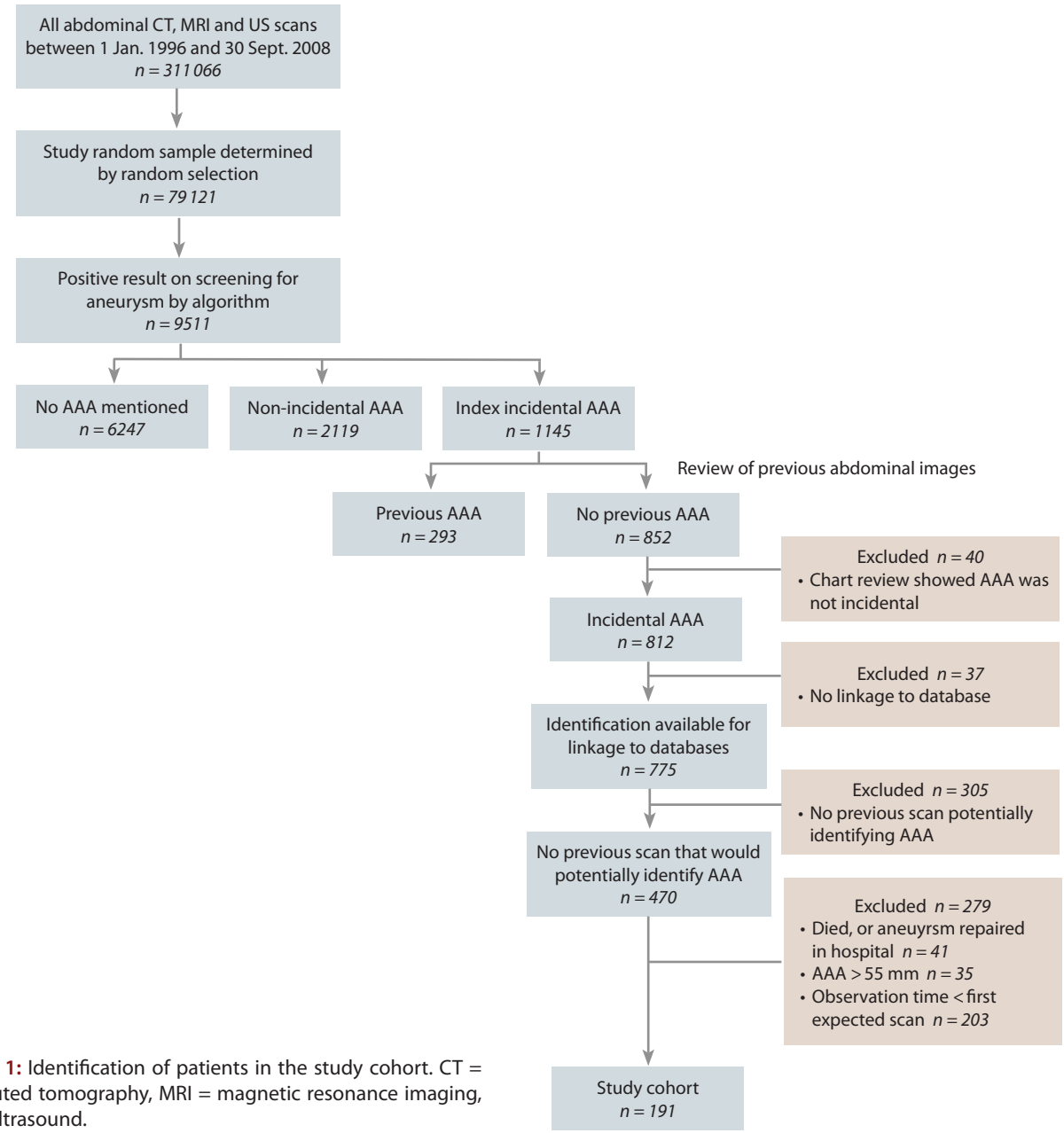

Figure 1: Identification of patients in the study cohort. CT = computed tomography, MRI = magnetic resonance imaging, US = ultrasound.

We linked to the OHIP database to identify all abdominal CT, US and MRI studies for patients in the cohort during their respective observation periods (using the codes listed in Appendix 1). We assumed that all such studies examined the AAA regardless of the reason for the imaging study. We used data from Brady and colleagues[8,9] to estimate the diameter of the AAA at any time during follow-up (Appendix 2). We compared this diameter with the 2005 guidelines of the Canadian Cardiovascular Society[11] to determine the recommended time to the next imaging study for monitoring of the AAA (Appendix 3). These guidelines are essentially identical with those of the American College of Cardiology / American Heart Association[12] and data-based recommendations from Brady and colleagues.[8] Brady[9] showed that the monitoring frequency in these guidelines reduced to 1% the risk of unmonitored AAA growth beyond 55 mm.

Outcomes. We used 2 outcomes to quantify incomplete monitoring. First, people who had no abdominal imaging during their observation time were classified as having had no monitoring. Second, we calculated the percentage of time with incomplete monitoring (defined as the total number of years without recommended radiographic monitoring divided by the years of observation). Total years without recommended radiographic monitoring was quantified according to the guidelines for appropriate frequency of AAA monitoring (Appendix 3). Based on the AAA diameter, we used this schedule to define within what period repeat radiographic AAA monitoring was recommended. When abdominal imaging was performed, we entered the baseline AAA diameter and the time to repeat imaging into a model to estimate the AAA size at follow-up (according to the equations in Appendix 2). We applied this process throughout the patient's observation period to calculate the total number of years without recommended radiographic monitoring (see Appendix 4, available online, for an example). Observation of a patient started when the incidental AAA was identified and ended at the earliest of elective AAA repair (identified in the DAD, according to codes listed in Appendix 1), admission to an emergency department or hospital for treatment of ruptured AAA (identified in the NACRS and DAD, respectively, according to codes listed in Appendix 1), death for any reason (identified in the RPDB) or 31 Mar. 2009 (the final date up to which all databases were current).

Potential confounders. Chronically ill patients are less likely to be candidates for surgical repair of AAA and are therefore less likely to undergo monitoring of an AAA. We therefore anticipated that controlling for comorbidity would help to reduce confounding of the analysis. We linked our cohort to population-based data sets to capture six measures of patient comorbidity. The general measures that we looked at were the number of emergency department admissions in the year before identification of the incidental AAA (i.e., baseline) (captured by linkage to the NACRS and OHIP database), the number of emergent hospital admissions in the year before baseline (from the DAD), whether the patient was living in a long-term care facility at baseline (from the OCCPS or the CCRS) and number of different drugs prescribed in the year before baseline (from the ODB). Data for number of medications were complete for all patients aged 65 years or older (81.2% of the cohort) and for those whose medications were paid through social assistance (unknown proportion of cohort). Disease-specific comorbidity measures were presence of diabetes mellitus (captured by linkage to the Ontario Diabetes Database, a population-based registry of Ontarians with diabetes) and acute coronary syndrome (captured by linkage to the Ontario Myocardial Infarction Database, a population-based registry of patients with myocardial infarction).[13]

We also adjusted for morbidity and risk of death using an index based on the Johns Hopkins Adjusted Clinical Groups System. This system assigns each International Classification of Disease code recorded during physician assessments in the community and hospital to 1 of 32 diagnostic clusters known as Aggregated Diagnosis Groups (ADGs). We recently derived and validated a multivariate logistic model to determine the independent association of each ADG with risk of death in the subsequent year.[12] This model (Appendix 5, available online) had excellent discrimination (*c* statistic 91.7%) and calibration (absolute difference between the observed probability of death and the mean predicted probability of death less than 0.01 in 97 of 100 centiles). For the study reported here, we calculated a "risk of death" score by summing the parameter estimates (see Appendix 5) for all ADGs applicable to each patient. This score was included in the study models to control for factors associated with the risk of death.

Analysis. We used multivariate binary logistic regression to determine the independent association of baseline factors with whether or not patients underwent any radiographic monitoring. For the percentage of time that a patient had incomplete monitoring, we used negative binomial regression (in which the outcome variable was the number of days the AAA was incompletely monitored

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

Characteristic	Overall n = 191	No monitoring n = 56	Some monitoring n = 135	Univariate *p* value*
Demographic				
Age, yr, mean (95% CI)	73.3 (71.9–74.6)	77.3 (75.0–79.7)	71.6 (70.1–73.1)	< 0.001
Sex, no. (%) female	49 (25.7)	19 (33.9)	30 (22.2)	0.09
Location of care				
The Ottawa Hospital – Civic Campus	64 (33.5)	21 (37.5)	43 (31.9)	0.60
The Ottawa Hospital – General Campus	104 (54.5)	27 (48.2)	77 (57.0)	
The Ottawa Hospital – other	23 (12.0)	8 (14.3)	15 (11.1)	
Clinical				
No. of emergency department visits in previous year, median (IQR)	0 (0–1)	0 (0–1)	0 (0–1)	0.88
No. of hospital admissions in previous year, mean (95% CI)	0.51 (0.39–0.63)	0.80 (0.53–1.07)	0.39 (0.27–0.51)	0.002
No. of drugs prescribed in previous year, median (IQR)	6 (1–10)	7 (3–11)	5 (0–10)	0.07
No. (%) transferred to hospital from long-term care facility	2 (1.0)	2 (3.6)	0 (0.0)	0.027
No. (%) with diabetes mellitus	46 (24.1)	14 (25.0)	32 (23.7)	0.85
No (%) with previous myocardial infarction	19 (9.9)	4 (7.1)	15 (11.1)	0.40
Aggregated Diagnosis Group score, mean (95% CI)†	1.23 (1.10–1.37)	1.45 (1.19–1.71)	1.14 (0.99–1.30)	0.038
Related to aneurysm				
Patient's location when aneurysm identified				
Community	135 (70.7)	39 (69.6)	96 (71.1)	0.47
Emergency department or hospital	56 (29.3)	17 (30.4)	39 (28.9)	
Infrarenal abdominal aortic aneurysm	170 (89.0)	50 (89.3)	120 (88.9)	0.94
Diameter of aneurysm, mm, mean (95% CI)	37.6 (36.6–38.6)	38.6 (36.8–40.5)	37.1 (35.9–38.3)	0.18

CI = confidence interval, IQR = interquartile range.

* Does not account for the influence of other variables in table.

† See Methods and Appendix 5 for full description.

and the offset variable was the total number of days of observation). Given the small sample size, we considered for inclusion only those variables that had a univariate association with each outcome of less than 0.2. For both models, we used backward variable selection, and retained variables with a significance level of 0.1.

We conducted several sensitivity analyses. First, we repeated the analysis adding the date of last contact with the health care system as a censoring variable (along with the date of death, date of rupture or repair of the AAA or 31 Mar. 2009). The date of a patient's last contact was the date of the last record in the OHIP, ODB, DAD or NACRS database. Second, to determine whether detailed comorbidity measures influenced monitoring of the AAA, we performed a formal chart review for patients who were admitted to hospital when the AAA was identified. We measured comorbidity using the validated Walter index[10] and determined whether physicians documented reasons why a patient would not be a candidate for monitoring. Finally, we determined whether hospital physicians reported the AAA to the patient's family physician in a discharge summary.

Results

Between January 1996 and September 2008, The Ottawa Hospital conducted 311 006 abdominal CT, US and MRI examinations (Fig. 1). We randomly selected 79 121 (25%) of these reports for electronic text screening. Of these, 9511 (12.0%) were "screen positive." Of the screen-positive reports, 812 indicated an incidental AAA (according to information in the report), but only 775 could be linked to population-based databases, and 470 of these had no previous abdominal imaging that would have identified the AAA. Of these 470 patients, 279 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 the patient's observation period did not extend beyond the first recommended monitoring scan (as in Appendix 3; n = 203).

The remaining cohort of 191 patients had an incidental AAA that required monitoring (Table 1). These patients were elderly (mean age 73.3 years), and most were men (74.3%). About one-quarter of them had diabetes, and 9.9% had previous myocardial infarction. The AAAs were small (mean diameter 37.6 mm), and most patients were

in the community when the AAA was identified. The median follow-up time was 4.4 years (range 0.6–12.7).

Monitoring of incidental AAAs. Fifty-six (29.3%) of the 191 patients in the study cohort had no monitoring of the incidental AAA (Table 1). Thirty-five of these patients (18.3% of the entire cohort) seemed healthy: they were no older than 70 years, they had not been living in a long-term care facility, and they had had no emergency department visits or hospital admissions in the previous year. At the univariate level, radiographic monitoring was less likely among elderly patients, patients with a higher number of hospital admissions, patients who had been admitted from a long-term care facility, and those with a greater ADG score; these results were statistically significant (Table 1). Radiographic monitoring was also less likely among women, patients with a higher number of medications, and those whose AAA was larger at baseline; these results were not statistically significant (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* radiographic monitoring. The adjusted odds of undergoing radiographic 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 the AAA. Overall, patients spent almost a fifth of their time with incomplete monitoring (median 19.4%, interquartile range [IQR] 0.3–44.0%). Forty-two patients (22.0%) spent more than 50% of their time with incomplete monitoring. The 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 the patient's age and diameter of the AAA (Table 3). In the multivariate model, monitoring was more incomplete for elderly patients, those with larger AAAs and those whose AAA was identified in the emergency department or the hospital (Table 3).

Table 2: Influence of baseline diameter of abdominal aortic aneurysm on time to first monitoring scan

Diameter (mm)	No. of patients	No. of years to first scan, mean (95% CI)	Recommended no. of years to first scan*	No. (%) of patients meeting recommended time to first scan
< 35	82	4.9 (3.3–6.5)	3	54 (66)
35–39	37	7.1 (4.3–9.9)	2	20 (54)
40–44	36	6.1 (3.7–8.4)	1	15 (42)
≥ 45	36	6.6 (3.8–9.4)	0.5	15 (42)

CI = confidence interval.
*Based on recommendations of the Canadian Cardiovascular Society.[11]

Table 3: Association between baseline patient-related factors and proportion of time that abdominal aortic aneuyrsm was incompletely monitored

Factor	Unadjusted		Adjusted	
	Relative rate* (95% CI)	*p* value	Relative rate* (95% CI)	*p* value
Age (per 10-yr increase)	1.29 (1.10–1.52)	0.002	1.27 (1.10–1.47)	0.001
Female	1.27 (0.90–1.80)	0.18	–	–
Median no. of emergency department visits in previous year	1.10 (0.79–1.52)	0.58	–	–
Mean no. of hospital admissions in previous year	1.23 (0.89–1.71)	0.21	–	–
No. of drugs prescribed in previous year	1.00 (0.98–1.03)	0.86	–	–
Transferred from long-term care	2.75 (0.90–8.41)	0.08	–	–
Diabetes mellitus	0.92 (0.63–1.33)	0.65	–	–
Previous myocardial infarction	0.67 (0.36–1.23)	0.20	–	–
Patient location (hospital or emergency department v. community)	1.56 (1.13–2.16)	0.007	1.34 (1.00–1.79)	0.05
Infrarenal abdominal aortic aneurysm	1.44 (0.85–2.44)	0.18	–	–
Diameter of aneurysm (per 10-mm increase)	1.75 (1.43–2.14)	< 0.001	1.65 (1.38–2.01)	< 0.001

CI = confidence interval.
*The relative rate represents the proportion of time, relative to a person without the factor, that a person with the factor spent with incomplete monitoring. For example, a relative rate of 1.5 indicates that the proportion of time with incomplete monitoring was 50% higher among those with than among those without the factor.

None of the comorbidity measures were associated with AAA monitoring.

Figure 2 displays the extent that factors from the multivariate model influenced the percentage of time with incomplete monitoring. These plots show the important effect on monitoring of both the patient's location when the AAA was identified and the baseline diameter of the AAA. Controlling for the other variables in the model, we found that 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 with 16.3%, 95% CI 12.0%–22.1%, for those whose AAA was identified in the community). Notably, patients whose AAA exceeded 45 mm in diameter 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%, 95% CI 12.0%–22.1%, for those with AAAs of diameter less than 35 mm).

Sensitivity analyses. Censoring patients' observations at the date of last contact with the health care system changed the observation time for only 14 people (7.3%) (mean decrease in observation time 3.2 months). The median time spent with incomplete monitoring did not change significantly: 17.9% (IQR 0%–41.0%) v. 19.4 (IQR 0.3%–44.0%). Parameter estimates of the regression model did not change significantly, but the p value for patient location increased to 0.18.

Thirty-seven people were in the hospital when their AAA was identified. We reviewed their charts to collect more information about baseline comorbidity and communication of their incidental AAA. Fourteen (37.8%) of these patients had a Walter index of 4 (which would be associated with a risk of death within 1 year exceeding 34%[10]), and a discharge summary identifying the AAA was sent to the family physician for 7 patients (18.9%). Neither the Walter index (p = 0.81) nor presence of a discharge summary communicating the AAA (p = 0.87) was significantly associated with percentage of time with incomplete monitoring.

Discussion

To our knowledge, this is the first examination of radiographic monitoring of incidental AAAs using population-based data. In our study cohort, monitoring of

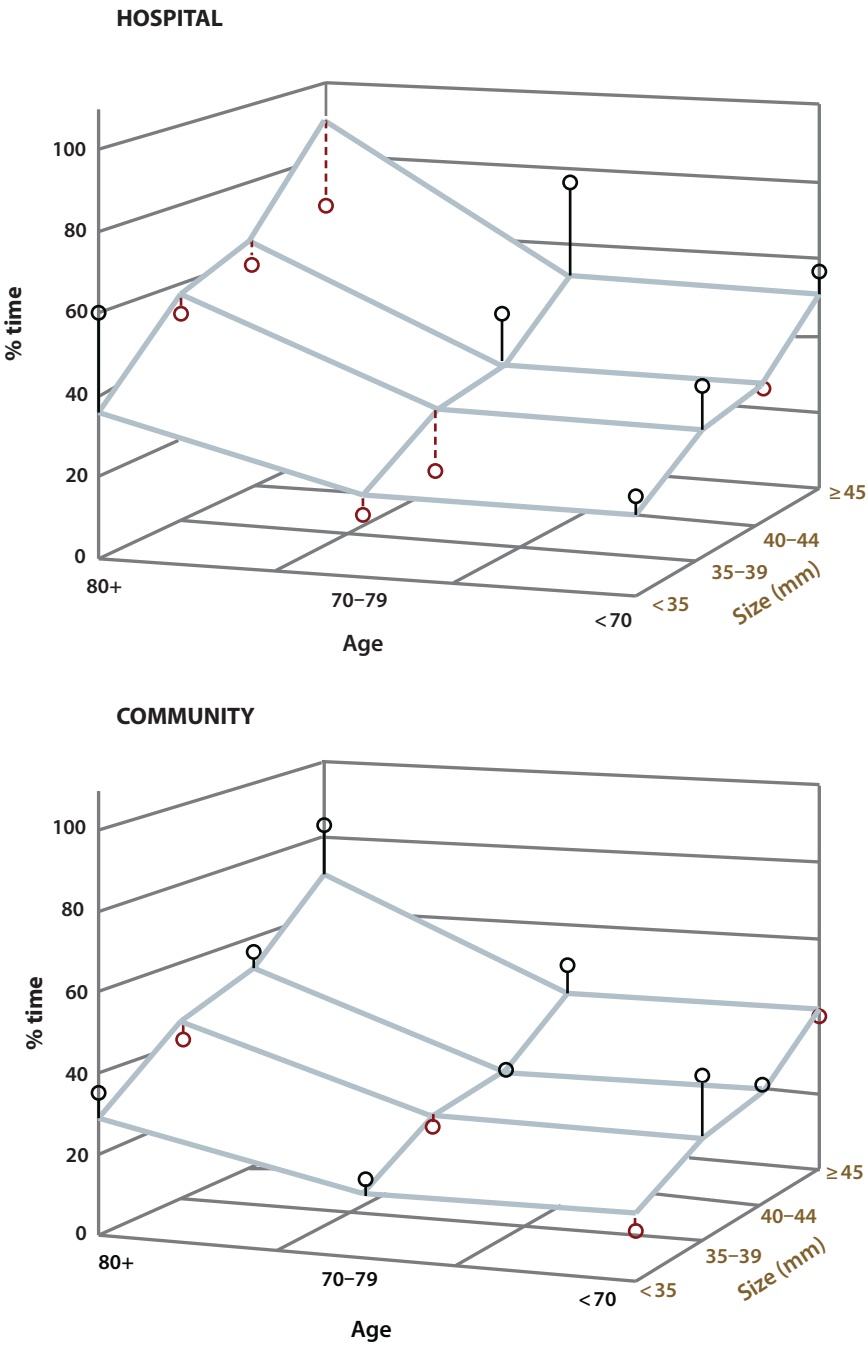

Figure 2: Independent association between important baseline factors and proportion of time for which a patient's abdominal aortic aneurysm was adequately monitored. This figure shows the relations between the patient's age (Age), the diameter of the aneurysm (Size) and the percentage of time without appropriate radiographic monitoring (% time), by the location where the abdominal aortic aneurysm was identified (hospital in the top component of the figure, and community in the lower component of the figure). 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.

incidental AAAs was incomplete. Almost one-third of people underwent no monitoring, and most of these people were seemingly healthy. Patients in the cohort spent almost one-fifth of their time with incomplete monitoring. Incomplete monitoring did not appear to be related to patient comorbidity. Further study is required to determine whether incomplete monitoring of incidental AAAs increases the risk of poor outcomes.

Radiographic monitoring of an AAA is not required for patients who are very ill and those with a short life expectancy. However, we do not believe that this explains the incomplete monitoring that we observed in this study. First, 35 (62%) of the 56 people with no monitoring appeared healthy (less than 70 years old, not in a nursing home and having had no emergency department visits or hospital admissions in the year before identification of the AAA). Second, the only comorbidity marker that was associated with incomplete monitoring was patient age. All other factors indicative of illness were not associated with AAA monitoring.

There are two potential explanations for the lack of association between completeness of monitoring and comorbidity. First, we may have incompletely captured comorbidity in our study, given that we quantified comorbidity on the basis of population-based administrative data, which may lack the clinical details required to completely define patients' sickness.[14] However, we do not believe that this completely explains our findings, because none of the large selection of comorbidity measures in our study (except age) influenced the completeness of monitoring. In addition, our sensitivity analysis for hospital inpatients showed no association between completeness of monitoring and the Walter index,[10] a validated index shown to predict the risk of death.

The second—and, we think, more likely—potential reason for the lack of association between incomplete AAA monitoring and patient comorbidity stems from the cause of the incomplete monitoring. If these incidental findings are being missed by physicians, comorbidity will not be associated with completeness of monitoring. Our observation that incidental AAAs identified in the emergency department or the hospital had more incomplete monitoring supports this hypothesis. Such AAAs are identified by physicians (i.e., emergency room physicians and hospitalists) who typically do not see patients after the acute treatment episode. If these physicians fail to communicate the incidental AAA to the patient or the regular physician (a situation that occurred for 74% of the patients in our original study[7]), then incomplete monitoring will not be associated with patient comorbidity. In addition, we previously found that 15 (21%) of 70 discharge summaries sent from the hospital to family physicians were subsequently not found in the patients' medical records.[3] We believe that unmonitored incidental AAAs represent another example of a "fumbled handoff."[15] Further work is required to clarify the factors that result in incomplete monitoring of incidental AAAs.

Our study had both a binomial outcome (proportion of patients with no repeat imaging) and a rate outcome (proportion of follow-up time with incomplete monitoring). The result for the binomial outcome (that almost one-third of patients had no follow-up monitoring) paints a more concerning picture than the result for the rate outcome (that almost one-fifth of patients' time was spent with incomplete monitoring). This distinction occurred because the rate outcome considers the index scan itself as an episode of AAA monitoring, with a monitoring duration that varies with the diameter of the index AAA (according to Appendix 3). However, because almost one-third of patients had *no* follow-up monitoring, counting the index AAA as monitoring could be interpreted as generous for a large proportion of people whose abnormalities appear to have been "dropped."

Several aspects of our study are notable. First, we are confident that our study included only newly identified incidental AAAs because we used population-based data to exclude all AAAs that might have been identified on previous abdominal imaging. With this approach, we may have excluded some incidental AAAs, because the act of imaging does not necessarily mean that a pathologic lesion was recognized. We focused our analysis on a restrictive subset of patients with truly incidental AAA because we felt that this would be the most realistic evaluation of the clinical phenomenon we are studying—specifically, the failure to act on incidental findings. Given this approach, our findings should not be used to estimate the burden of unrecognized AAAs in our study population. Second, we were struck by the fact that larger AAAs were not being monitored more frequently than smaller AAAs. In fact, patients 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 3). It could also indicate that follow-up was haphazard for some of the incidental AAAs. 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. The recommended monitoring schedules (Appendix 3) were created to decrease the risk that AAAs would grow undetected into this size range, so it might be expected that incomplete monitoring would

increase the risk of rupture. Further analyses are required to determine if this is indeed the case.

Some other limitations of our study should be noted. Our model did not include any information about the physician who ordered the radiographic imaging. It is possible that including physician characteristics, such as clinical experience or specialty, in the model would have explained much of the variation that we observed. Second, we are uncertain if incidental AAAs are incompletely monitored in other centres. Our results suggest that incidental AAAs are more likely to be incompletely monitored when someone other than the patient's regular physician orders the imaging study. In such a case, poor communication between the ordering physician and the regular physician will result in information about the AAA being overlooked. It is possible that health care systems with better integration than ours would have better monitoring of incidental AAAs. Finally, although we believe that this is the largest cohort of patients with incidental AAA whose radiographic monitoring has been tracked over a long period, our study sample contained fewer than 200 people from a single institution. Therefore, the generalizability of these results to other institutions still needs to be established.

Several interventions could improve the monitoring of incidentally identified AAAs. The radiologist could directly contact the ordering physician about identification of a 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 frequency of repeat abdominal imaging. Patients without a family physician could be automatically booked for follow-up abdominal imaging within the recommended timeframe (Appendix 3) or referred to a vascular surgeon. 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.

Contributors: CvW and AF conceived the study; CvW, AF, and PJ contributed to study design; AF, JW, KM, and AJ helped with acquisition of data; CvW, JW, and PA contributed to the analysis; CvW, JW, KM, AJ, PA, PJ, and AF contributed to 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.

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