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Surveillance Imaging Following Acute Type A Aortic Dissection

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ABSTRACT

BACKGROUND Survivors of acute type A aortic dissection (ATAAD) repair remain at risk for long-term complications. Guidelines recommend postoperative imaging surveillance, but adherence is uncertain.

OBJECTIVES The aim of this study was to define the real-world frequency of postoperative imaging and characterize long-term outcomes of ATAAD.

METHODS Population-based administrative health databases for Ontario, Canada, were linked to identify patients who underwent ATAAD repair and survived at least 90 days. Guideline-directed imaging surveillance (GDIS) was defined as undergoing a computed tomographic or magnetic resonance imaging scan at 6 and 12 months postoperatively and then annually thereafter. Multivariable time-to-event analysis explored the associations between GDIS and all-cause mortality and reintervention.

RESULTS A total of 888 patients who survived urgent ATAAD repair between April 1, 2005, and March 31, 2018, were included. Median follow-up after ATAAD repair was 5.2 years (interquartile range: 2.4-7.9 years). A total of 14% patients received GDIS throughout follow-up. At 6 years, 3.9% of patients had received GDIS. The mortality rate was 4% at 1 year, 14% at 5 years, and 29% at 10 years. Incidence of aortic reintervention was 3% at 1 year, 9% at 5 years, and 17% at 10 years; the majority of these were urgent (68%), and they carried a 9% 30-day mortality rate. Greater adherence to GDIS was associated with mortality (hazard ratio: 1.08; 95% confidence interval: 1.05-1.11) and reintervention (hazard ratio: 1.04; 95% confidence interval: 1.01-1.07).

CONCLUSIONS Adherence to GDIS following ATAAD repair is poor, while long-term mortality and reinterventions remain substantial. Further research is needed to determine if guidelines should be modified.
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Following repair of acute type A aortic dissection (ATAAD), there is commonly residual dissection in the native aorta that remains at risk for continual aneurysmal degeneration and rupture (1,2). As a result, an estimated 10%-20% of patients may need reintervention in the first 10 years following type A dissection repair, in the root, arch, or thoracoabdominal aorta (3). Furthermore, the risk for aortic dilation does not subside over time. Zierer et al (4) reported that distal aortic dilation could occur more than a decade after initial surgery, supporting the value of lifelong imaging surveillance to prevent future aortic catastrophe. As such, the 2010 American College of Cardiology/American Heart

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ABBREVIATIONS AND ACRONYMS

ATAAD = acute type A aortic dissection

EVAR = endovascular infrarenal abdominal aortic aneurysm repair

GDIS = guideline-directed imaging surveillance

Association guidelines suggest computed tomography or magnetic resonance imaging before discharge; at 1, 6, and 12 months; and yearly thereafter in acute aortic dissection (5).

The degree of adherence to guideline-directed imaging surveillance (GDIS) after ATAAD repair is uncertain. Discordance between guideline recommendations and real-world practice may be expected because of a paucity of evidence supporting the clinical benefit of imaging surveillance postdissection. Furthermore, diligent lifelong serial imaging follow-up is challenging and costly and may be viewed as burdensome among asymptomatic patients, particularly those living far from a tertiary care center (6). There may also be a knowledge gap among patients and some clinicians that the residual native aorta is at risk for late complications after successful repair of ATAAD. The aim of this study was to characterize the real-world frequency of postoperative imaging after ATAAD repair in Ontario, Canada, and to evaluate the association between imaging surveillance and long-term outcomes.

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METHODS

STUDY DESIGN AND SETTING. We performed a population-based retrospective cohort study of patients with ATAAD undergoing surgical repair between April 1, 2005, and March 31, 2018, in Ontario, Canada. Ontario is Canada's most populous province with >14 million residents. There are 11 cardiac surgery centers delivering elective and urgent care, and there are no private cardiac surgery centers. All hospital and physician services related to ATAAD repair and postoperative follow-up are fully funded under the provincial single-payer health care system.

This project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a research ethics board.

DATA SOURCES. ATAAD repair, subsequent imaging, aortic reintervention, and mortality were captured in population-based administrative health datasets held at ICES (formerly known as the Institute for Clinical Evaluative Sciences) (7). Ontario resident status, demographics, and, if applicable, death were captured in the Registered Persons Database. ATAAD repair and aortic reintervention were captured in the Discharge Abstract Database, which includes records on all hospitalizations in Ontario. The Ontario Health Insurance Plan Physician Claims Database allowed the capture of all computed tomographic or magnetic resonance imaging of the aorta following ATAAD repair. These datasets were deterministically linked using unique encoded identifiers and analyzed at ICES.

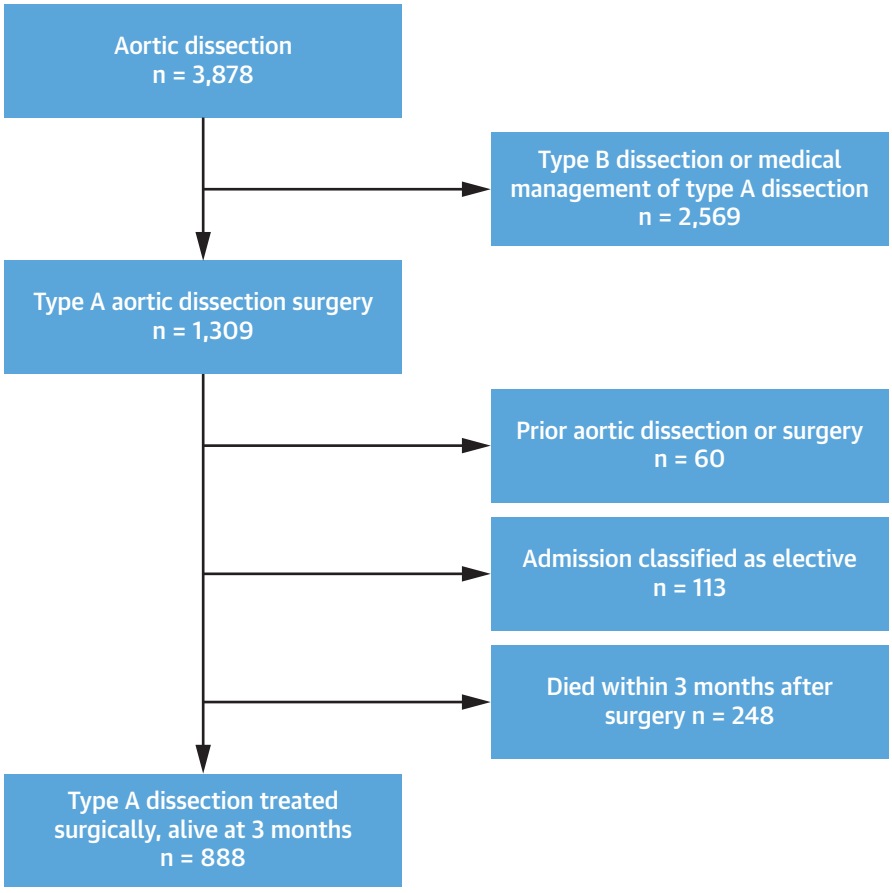
TYPE A DISSECTION REPAIR COHORT. The cohort included patients admitted to the hospital with a diagnosis of aortic dissection (International Statistical Classification of Diseases and Related Health Problems-10th Revision-Canada code I71.0) who underwent urgent or emergent open surgical repair of the aortic root, valve, ascending aorta, or arch of the aorta within the index hospitalization (Supplemental Appendix A). Patients were excluded if they had aortic dissection or ascending aorta or aortic arch surgery in the previous 10 years or were treated with open thoracoabdominal surgery (Supplemental Appendix B). Only patients surviving past 90 days after surgery were included in order to obtain a cohort for whom imaging surveillance was indicated.

BASELINE CHARACTERISTICS. Baseline characteristics included age, sex, rurality, Charlson comorbidity index, and specific comorbidities: congestive heart failure, connective tissue disorder, chronic obstructive pulmonary disease, cerebrovascular disease, dementia, diabetes, dyslipidemia, hypertension, chronic kidney disease, myocardial infarction, peripheral vascular disease, and body mass index >40 kg/m^2 (8). Additional covariates included hospital volume of ATAAD repairs in the preceding year.

EXPOSURE DEFINITION. Postoperative imaging surveillance was identified through the Ontario Health Insurance Plan physician's billing database and included chest computed tomography with or without contrast, cardiac gated computed tomographic angiography, and magnetic resonance imaging of the thorax (Supplemental Appendix C). The guideline-directed imaging schedule was defined as 6 months and 12 months, followed by annual scans. To reflect the reality of booking challenges and missed appointments, a 3-month buffer was incorporated into the definition: the 6-month scan could occur between 3 and 9 months following ATAAD repair (6 ± 3 months), the 12-month scan between 9 and 15 months, and each annual scan thereafter up to 15 months from the previous scan.

During the follow-up period, patients were considered to be in a time-varying state of compliance with GDIS; in other words, patients may permanently or temporarily fall off the follow-up imaging schedule. In characterizing the association between GDIS (the exposure) and outcomes, we therefore considered 2 different exposure definitions: 1) a binary time-varying exposure definition whereby if a patient missed GDIS at any point, he or she

FIGURE 1 Flow Diagram for Patient Inclusion



The cohort included 888 patients living in Ontario from 2005 to 2018 who presented with primary acute type A aortic dissection requiring emergency repair, who then went on to survive for 3 months after surgery.

was considered as no longer having GDIS for the remainder of their follow-up; and 2) a continuous time-varying exposure definition: the proportion of time adherent to GDIS, which reflects a patient who moves between periods of having and not having GDIS.

OUTCOME DEFINITIONS. The primary outcome was all-cause mortality. The secondary outcome was aortic reintervention (Supplemental Appendix D). Reintervention was defined as any aortic operation occurring at least 3 months after the initial surgery. This was done to exclude patients who had planned multistage interventions. Reinterventions were further classified as either elective or urgent according to their admission status.

STATISTICAL ANALYSES. Categorical variables are presented as numbers (percentages), and continuous variables are presented as mean ± SD or median (interquartile range [IQR]). Baseline characteristics for the entire cohort are presented. Mortality and reintervention or death over time were quantified as Kaplan-Meier estimates. Reintervention over time was also quantified as a cumulative incidence that accounts for death as competing risk (9). Patients were censored if they underwent aortic repair (for primary outcome only) or reached maximum follow-up (March 31, 2019) but had not died.

The association between GDIS and mortality, adjusted for potential confounders, was characterized using Cox proportional hazard regression models. The association between GDIS and reintervention, adjusted for potential confounders, was characterized using cause-specific hazard regression, which accounts for death as a competing risk (9). We used 2 exposure definitions for time-varying compliance: binary and continuous definitions, as previously described. All previously listed

TABLE 1 Baseline Characteristics of Patients Who Underwent Surgical Repair of Acute Type A Aortic Dissection (N = 888)

Demographics	
Age, y	61 (51-71)
Male	624 (70.3)
Comorbidities	
Charlson comorbidity index	0.48 ± 0.98
Congestive heart failure	78 (8.8)
Connective tissue disorder	9 (1.0)
Chronic obstructive pulmonary disease	144 (16.2)
Cerebrovascular disease (all)	29 (3.3)
Cerebrovascular disease (ischemic stroke only)	18 (2.0)
Dementia	10 (1.1)
Diabetes	95 (10.7)
Dyslipidemia	229 (25.8)
Hypertension	578 (65.1)
Chronic kidney disease	35 (3.9)
Myocardial infarction	54 (6.1)
Peripheral vascular disease	37 (4.2)
Body mass index >40 kg/m^2	23 (2.6)
Socioeconomic factors	
Urban place of residence	779 (87.7)
Income quintile	
1 (lowest)	184 (20.7)
2	168 (18.9)
3	177 (19.9)
4	170 (19.1)
5 (highest)	189 (21.3)

Values are median (interquartile range), n (%), or mean ± SD.

baseline characteristics were included in the models as potential confounders on clinical grounds. There were no missing data with respect to exposure or outcomes. A 2-sided P value of <0.05 was considered statistically significant.

RESULTS

POPULATION AND BASELINE CHARACTERISTICS. A total of 888 patients who underwent successful urgent or emergent repair of ATAAD from 2005 to 2018 and survived for a minimum of 3 months were included in the final cohort (Figure 1). The median age of the cohort was 61 years (IQR: 51-71 years), and 70% of patients were men. Similar to Ontario's urban/rural population distribution, 87.5% of patients lived in urban areas (Table 1). The mean number of dissection cases admitted per hospital was 21 ± 9 per year. Across 11 hospitals, the highest quintile of volume by center was a mean of 35 ± 9 cases per year, and the lowest quintile was a mean of 10 ± 3 cases per year. The median follow-up duration for the cohort was 5.2 years (IQR: 2.4-7.9 years).

SURVIVAL AND AORTIC REINTERVENTION AFTER TYPE A DISSECTION REPAIR. Overall, the mortality rate was 4% at 1 year, 14% at 5 years, and 29% at 10 years (Figure 2). The cumulative incidence of aortic reintervention, considering death a competing risk, was 3% at 1 year, 9% at 5 years, and 17% at 10 years (Figure 3). At latest follow-up, 101 aortic reinterventions (11%) were performed: 69 (68%) were urgent and 32 (32%) were elective. The mortality rate within 30 days of any aortic reintervention was 9% (9 of 101). Reintervention or death for the entire cohort was 6% at 1 year, 21% at 5 years, and 39% at 10 years (Figure 4).

ASSOCIATION BETWEEN GDIS AND OUTCOMES. Overall, 128 patients (14%) had GDIS over their entire follow-up, with the proportion of patients remaining fully compliant dropping quickly within 2 years to 21% and to <2% at 8 years after ATAAD repair (Table 2). Averaged across all available follow-up intervals, 44% of total patient follow-up time was spent with adherence to GDIS after ATAAD repair. Hospital yearly volume of ATAAD repair was not associated with GDIS adherence (linear regression, $P = 0.37$).

In the first multivariable model, with a binary time-varying definition of full compliance, there was no statistically significant association between having GDIS and mortality (hazard ratio [HR]: 1.37; 95% confidence interval [CI]: 0.92-2.04). However, there was however an association between having GDIS and reintervention (HR: 1.81; 95% CI: 1.14-2.85).

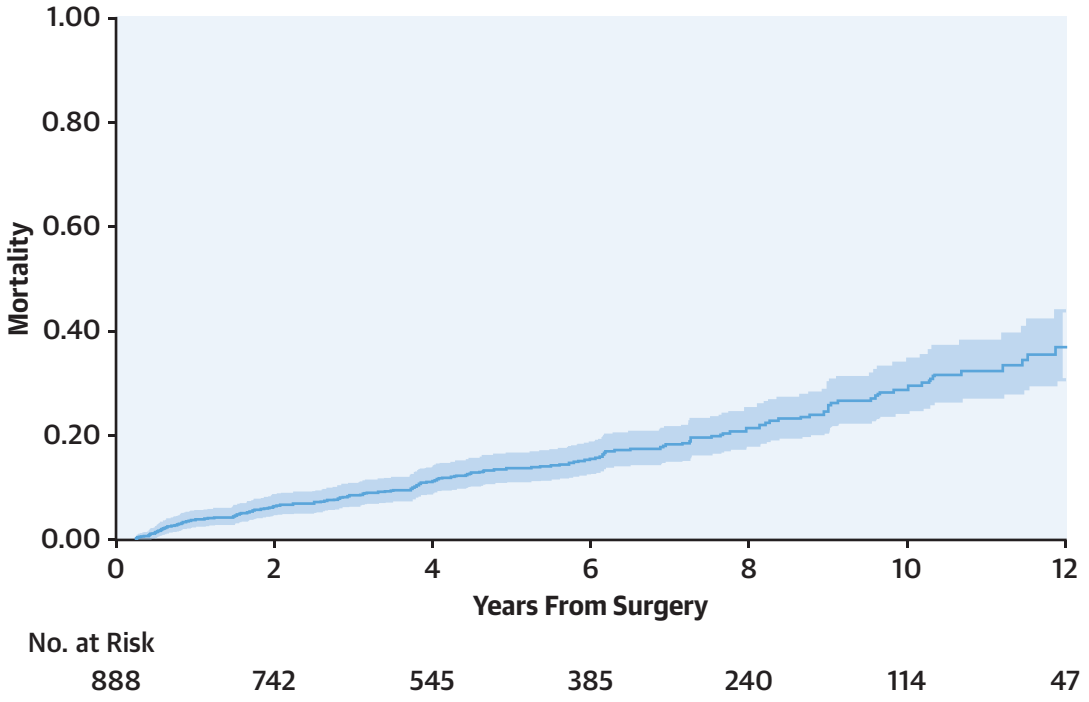
In the second multivariable model, using the continuous time-varying definition of compliance, a 10% increase in time spent in compliance with GDIS was associated with an increased risk for mortality (HR: 1.08; 95% CI: 1.05-1.11) and reintervention (HR: 1.04; 95% CI: 1.01-1.07).

RISK FACTORS FOR MORTALITY AND REINTERVENTION. Risk factors for mortality included increased age (HR: 1.05; 95% CI: 1.03-1.07), higher Charlson comorbidity index (HR: 1.29; 95% CI: 1.10-1.50), chronic kidney disease (HR: 1.97; 95% CI: 1.01-3.86), and the lowest quintile of neighborhood income (HR: 1.61; 95% CI: 1.01-2.57), while female sex was a protective factor (HR: 0.66; 95% CI: 0.45-0.95) (Supplemental Appendix E). Protective factors for reintervention included increased age (HR: 0.97; 95% CI: 0.96-0.99) and female sex (HR: 0.54; 95% CI: 0.31-0.93) (Supplemental Appendix F).

DISCUSSION

In the first population-based study reporting the real-word frequency of long-term surveillance imaging after ATAAD, we found that adherence to guidelines was extremely poor, with only 14% of patients having GDIS during their follow-up period

FIGURE 2 Long-Term Mortality Following Acute Type A Aortic Dissection Repair



The Kaplan-Meier curve of the probability of survival in patients undergoing acute type A aortic dissection surgery who survived the initial 90 days postoperatively demonstrated mortality rates of 4% at 1 year, 14% at 5 years, and 29% at 10 years. **Shaded area** represents the 95% confidence interval.

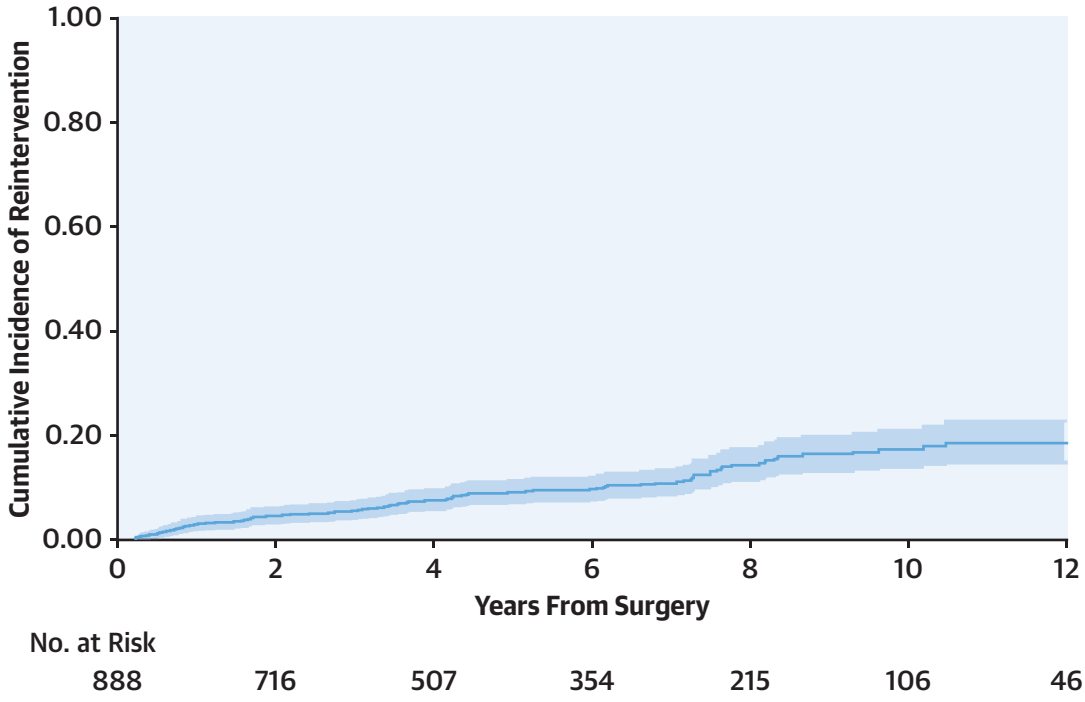
(Central Illustration). In patients who survived the initial 3 months, mortality after ATAAD repair was found to be 29% at 10 years, and aortic reintervention rates were 17% at 10 years. The majority of reinterventions were urgent, and they carried a 9% mortality rate, supporting the need to improve current levels of imaging surveillance after ATAAD.

The low rate of imaging surveillance we found following type A dissection repair was striking. The observed 21% GDIS at 2 years and <4% GDIS at 6 years compares starkly with 80% at 2 years in a similarly conducted study of imaging follow-up after endovascular infrarenal abdominal aortic aneurysm repair (EVAR) in Ontario (10). Unlike EVAR patients, who are uniformly followed by vascular surgeons, those surviving ATAAD repair may be orphaned in follow-up, unclear of who is managing their residual aortic dissection after a catastrophic event. Surveillance imaging modality and frequency may vary depending on whether the patient is followed by general practitioners, cardiologists, vascular surgeons, or cardiac surgeons. The low rate of follow-up imaging may also be due to assumptions around the durability of open repair for type A aortic dissections. Another potential contributing factor is that surgeries for type A dissection are often done at referral centers, possibly far from a patient's place of residence, which may factor into loss of follow-up and decreased imaging surveillance. Previous studies have shown an association between distance from referral center and complete follow-up or mortality in EVAR (11,12).

Long-term survival following initial ATAAD repair was encouraging and supports observations from the NORCAAD (Nordic Consortium for Acute Type A Aortic Dissection) registry, in which 5- and 8-year survival were 86% and 76%, respectively, with a linearized mortality rate of 3.4% per patient-year (13). The reintervention rates in our study of 17% at 10 years were at the lower end compared with previous smaller single-center studies, whose rates ranged from 16% to 28% at 10 years (3,4,14).

We observed that GDIS was associated with increased mortality and reintervention. In contrast, previous studies conducted in patients undergoing EVAR have shown either a decrease in mortality with imaging surveillance or no difference (10,15). There

FIGURE 3 Cumulative Incidence of Reintervention After Acute Type A Dissection Surgery

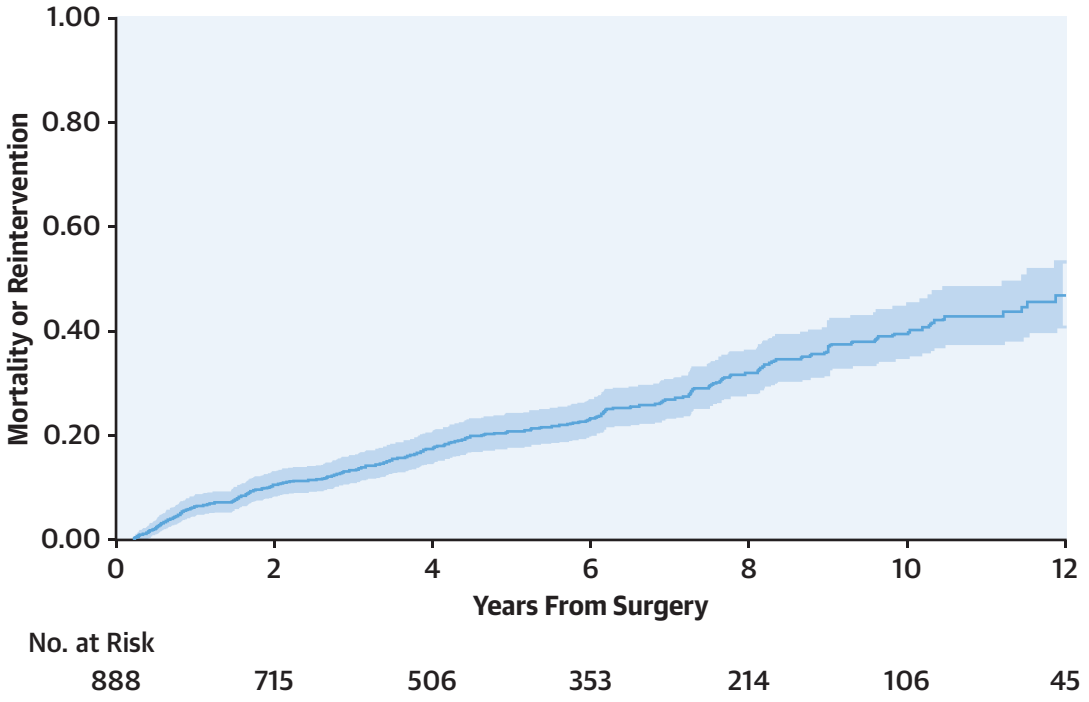


The cumulative incidence of aortic reintervention, considering death a competing risk, in patients undergoing type A aortic dissection repair who survived the initial 90 days postoperatively was 3% at 1 year, 9% at 5 years, and 17% at 10 years. **Shaded area** represents the 95% confidence interval.

may be several explanations for this observation. First, as the indication for imaging in our study was not captured, follow-up imaging may have been prompted by symptoms or concerns regarding aorta-related complications. Alternatively, patients with more significant medical comorbidities (eg, lung cancer, pulmonary embolism, coronary artery disease) could have undergone imaging for unrelated reasons more frequently. It is also possible that patients who underwent more frequent imaging had higher risk features at the time of the index operation, such as large residual native aortas, patent false lumen, limited repair of an extensive dissection, or connective tissue disease. Patients may also have had more rapid interval growth between scans, prompting more frequent imaging, aortic reinterventions, and higher overall mortality from a more malignant aortic course.

With so few patients in this particular population actually receiving the recommended imaging surveillance, the effect of close follow-up on altering outcome could not be shown. Yet, as the evidence for it is poor, guidelines could consider reevaluation of mandated imaging surveillance schedules as blanket recommendations. A tailored approach to imaging depending on risk for long-term complications could potentially reduce the burden and risks of unnecessary imaging surveillance on patients and the health care system while maximizing the benefits of imaging surveillance. As an example, the Canadian position statement on the management of thoracic aortic disease offers more flexibility in terms of imaging surveillance with follow-up imaging every 6 to 12 months or less depending on the presence of residual aortopathy and observed rate of aortic growth (16). However, there remains a lack of granularity and practical guidance for aortic clinics in following the variety of aortic pathology seen postdissection, highlighting an area for further research. Nuances are plentiful, including the presence of a residual dissection, patent or partially thrombosed false lumen, increased aortic diameter, younger age, inadequate blood pressure control, and the presence of connective tissue disease, which are reported risk factors for subsequent aortic dilation and need for reintervention (17-20). We suggest that such complex decision making may be best provided by aortic specialists at increasingly common dedicated aortic clinics. It is also likely that improved follow-up would

FIGURE 4 Probability of Reintervention or Death After Type A Dissection Surgery



The Kaplan-Meier curve of the probability of reintervention-free survival in patients undergoing acute type A aortic dissection surgery who survived the initial 90 days postoperatively demonstrated that the probability of aortic reintervention or death was 6% at 1 year, 21% at 5 years, and 39% at 10 years. **Shaded area** represents the 95% confidence interval.

be seen in such settings, as the local physicians to whom these patients return after discharge may be unaware of the need for ongoing imaging. With the advent of telehealth, accelerated during the global coronavirus disease 2019 pandemic, remote communities will benefit from increased access to aortic specialists.

STUDY LIMITATIONS. Certain details are not captured in administrative databases. For example, specific anatomical characteristics of type A dissection that may stratify patients in terms of risk for future aortic events, such as the presence of residual dissection, were unavailable. The cause of death, whether aorta related or otherwise, could not be captured. Individual surgeon-level data are also not captured. Furthermore, the indication for the reintervention, whether for symptoms or imaging, is unclear, although most reinterventions were urgent. Finally, we were not able to accurately distinguish the reason for imaging, the implications of which were discussed earlier. As with all observational retrospective studies, unmeasured or unknown confounders may bias the outcome.

TABLE 2 Proportion of Patients Fully Compliant With Imaging Follow-Up by Time From ATAAD Repair

Time From ATAAD Repair	Number of Surviving Patients	Proportion of Patients With GDIS[a]
90 d	888	100 (888)
2 y	742	20.6 (153)
4 y	545	9.4 (51)
6 y	385	3.9 (15)
8 y	240	≤2.1 (≤5)[b]

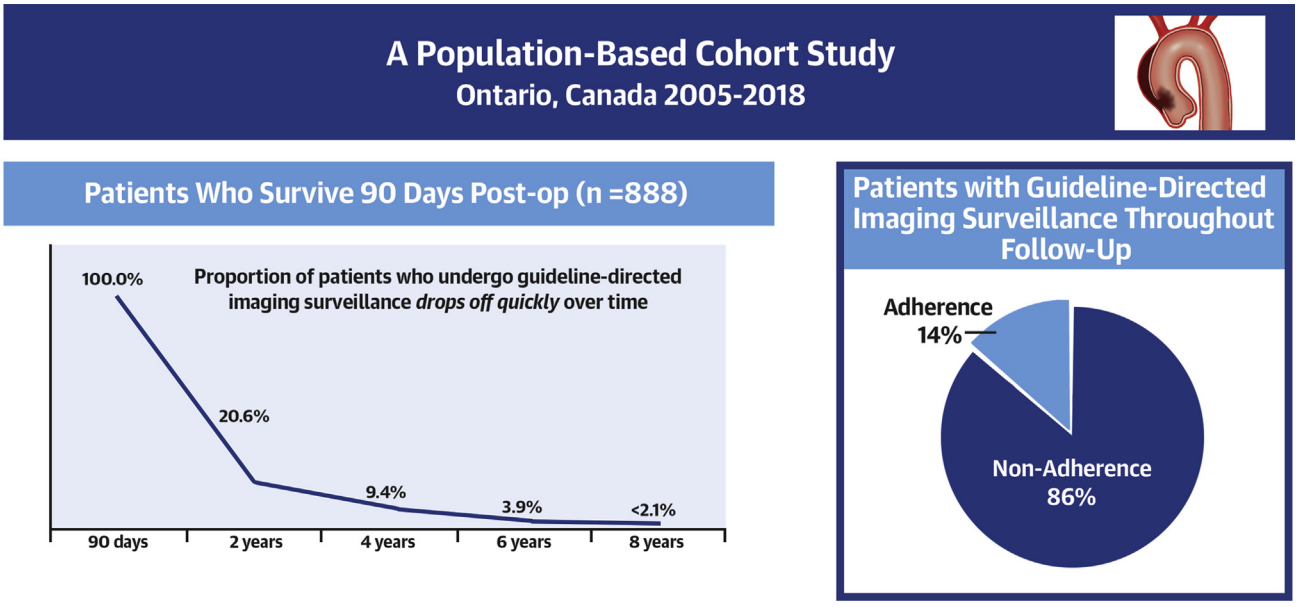
Values are % (n) unless otherwise indicated. [a]GDIS was defined as having 6-month, 12-month, and then annual computed tomographic or magnetic resonance scans of the chest; see exposure definition for further details. [b]Cell suppressed because of small count.

ATAAD = acute type A aortic dissection; GDIS = guideline-directed imaging surveillance.

CONCLUSIONS

Our study identified that adherence to GDIS is very poor in the Ontario population, a single-payer healthcare system. Long-term mortality and reinterventions after surviving type A dissection repair remain substantial. Given the low adherence to the GDIS schedule, a tailored approach to selecting patients for strict imaging surveillance led by aortic

CENTRAL ILLUSTRATION **Long-Term Imaging Surveillance After Acute Type A Aortic Dissection Repair**



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Key findings of this population-based cohort study of 888 patients are highlighted. The proportion of patients who underwent guideline-directed imaging surveillance dropped off quickly over time, and only 14% of patients adhered to guideline-directed imaging surveillance throughout their follow-up period. The study demonstrated a 71% survival rate and 17% reintervention rate at 10 years.

experts rather than a generalized protocol for imaging surveillance may be needed for this complex population.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: Failure to adhere to GDIS after ATAAD repair is widespread in clinical practice, and selecting patients for diligent imaging surveillance led by experts in aortic disease may improve long-term clinical outcomes.

TRANSLATIONAL OUTLOOK: Further efforts are needed to identify barriers to optimal imaging surveillance among survivors of ATAAD and facilitate compliance with GDIS.

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KEY WORDS aortic dissection, computed tomography, magnetic resonance imaging

APPENDIX For supplemental tables, please see the online version of this paper.