Late diagnosis of abdominal aortic aneurysms substantiates underutilization of abdominal aortic aneurysm screening for Medicare beneficiaries

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Objective: **Abdominal aortic aneurysm (AAA) screening remains largely underutilized in the U.S., and it is likely that the proportion of patients with aneurysms requiring prompt treatment is much higher compared with well-screened populations. The goals of this study were to determine the proportion of AAAs that required prompt repair after diagnostic abdominal imaging for U.S. Medicare beneficiaries and to identify patient and hospital factors contributing to early vs late diagnosis of AAA.**

Methods: **Data were extracted from Medicare claims records for patients at least 65 years old with complete coverage for 2 years who underwent intact AAA repair from 2006 to 2009. Preoperative ultrasound and computed tomography was tabulated from 2002 to repair. We defined early diagnosis of AAA as a patient with a time interval of greater than 6 months between the first imaging examination and the index procedure, and late diagnosis as patients who underwent the index procedure within 6 months of the first imaging examination.**

Results: **Of 17,626 patients who underwent AAA repair, 14,948 met inclusion criteria. Mean age was 77.5 ± 6.1 years. Early diagnosis was identified for 60.6% of patients receiving AAA repair, whereas 39.4% were repaired after a late diagnosis. Early diagnosis rates increased from 2006 to 2009 (59.8% to 63.4%; $P < .0001$) and were more common for intact repair compared with repair after rupture (62.9% vs 35.1%; $P < .0001$) and for women compared with men (66.3% vs 59.0%; $P < .0001$). On multivariate analysis, repair of intact vs ruptured AAAs (odds ratio, 3.1; 95% confidence interval, 2.7-3.6) and female sex (odds ratio, 1.4; 95% confidence interval, 1.3-1.5) remained the strongest predictors of surveillance. Although intact repairs were more likely to be diagnosed early, over one-third of patients undergoing repair for ruptured AAAs received diagnostic abdominal imaging greater than 6 months prior to surgery.**

Conclusions: **Despite advances in screening practices, significant missed opportunities remain in the U.S. Medicare population for improving AAA care. It remains common for AAAs to be diagnosed when they are already at risk for rupture. In addition, a significant proportion of patients with early imaging rupture prior to repair. Our findings suggest that improved mechanisms for observational management are needed to ensure optimal preoperative care for patients with AAAs. (J Vasc Surg 2013;57:1519-23.)**

Abdominal aortic aneurysms (AAAs) remain a common problem in the elderly and recent efforts have focused on early diagnosis as a mechanism to improve outcomes. Previous studies have demonstrated that AAA screening markedly decreases aneurysm-related mortality.[1] Current recommendations by the U.S. Preventative Services Task Force and the Society of Vascular Surgery include a screening ultrasound examination for 65- to 75-year-old at-risk individuals[2] defined as men with a smoking history of greater than 100 cigarettes or any person with a family history of AAAs. In a well-screened population, the vast majority of AAAs should be diagnosed early when the aneurysm is still small. "Early diagnosis" patients can be observed and treated surgically when the AAA meets size criteria for repair. Even in a well-screened population, approximately 10% to 12% of those found to have an AAA at initial screening will have an aneurysm that already meets size criteria for prompt repair,[3,4] constituting a "late diagnosis" cohort. It is likely that the proportion of those with a late AAA diagnosis will be much higher in less well-screened populations.

Even with expansion in insurance coverage for screening in the elderly, AAA screening appears to be largely underutilized in the U.S.[5] The goal of this study was to document the preoperative imaging history for Medicare beneficiaries who underwent AAA repair in the U.S., with particular emphasis on determining the proportion of AAAs that required prompt repair after diagnostic abdominal imaging. We also sought to investigate patient and hospital factors contributing to early versus late diagnosis of AAA.

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Supported in part by a Seed Grant From the Stanford University School of Medicine Cardiovascular Institute.

Author conflict of interest: none.

Presented at the Twenty-seventh Annual Meeting of the Western Vascular Society, Park City, Utah, September 22-25, 2012.

Additional material for this article may be found online at www.jvascsurg.org.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214/$36.00

http://dx.doi.org/10.1016/j.jvs.2012.12.034

METHODS

Data sources. We used data from 2002 to 2009 Medicare claims for a 20% random sample of traditional fee-for-service beneficiaries and identified study variables from inpatient claims from the Medicare Provider and Analysis Review (MedPAR, part A) files and physician claims from Carrier (part B) files. These files contain information for all hospitalizations and physician services that were billed to the Center for Medicare and Medicaid Services. We identified diagnoses and hospital procedures using International Classification of Diseases, ninth revision, clinical modification (ICD-9-CM) codes recorded on inpatient claims and physician procedures using current procedure terminology codes. We obtained demographic data, enrollment information including enrollment gaps or enrollment in Medicare Advantage, and death information from Medicare denominator or beneficiary summary files.

Patient events. We identified patients who underwent AAA repair between January 1, 2006 and December 31, 2009 by a hospitalization with a diagnosis code for intact AAA (ICD-9-CM codes 441.4 or 441.9) or ruptured AAA (441.3, 441.5) and a procedure code for AAA repair (ICD-9-CM codes 38.34, 38.44, 38.64, 38.92, or 39.71). We designated the first such claim as the index procedure and the date of the repair as the index date. Beneficiaries younger than 67 years old on the index date were excluded to ensure the presence of a complete claims record for at least 2 years prior to the index procedure.

We defined a follow-back period for each patient in the cohort. For patients with index date in 2006 and 2007, we followed claims back to January 1, 2002 or the beneficiary's 65th birthday, whichever was later; for index dates in 2008 or 2009, we followed claims back to January 1 of 2003 or 2004, respectively, or the beneficiary's 65th birthday, whichever was later. This ensured a follow-back period of 2 to 5 years for all beneficiaries in the study. We excluded beneficiaries with any Medicare Advantage (part C) enrollment or those with incomplete part A or part B coverage during their follow-back period because claims for these patients were incomplete.

We identified preoperative imaging data during the follow-back period, including ultrasound (current procedure terminology codes 76700, 76705, 76770, 76775, G0389, 93975, 93976, 93978, 93979), computerized tomography (CT) (codes 72191, 72192, 72193, 72194, 74150, 74160, 74170, 74175, 74176, 74177, 74178, 74261, 74262, 74263, 75635) and magnetic resonance imaging (codes 74181, 74182, 74183, 74184, 74185, 72195, 72196, 72197, 72198) of the abdomen. We combined codes of the same modality on the same day as one examination to avoid overcounting from multiple codes from a single examination. For example, we considered a patient with a code for a CT scan of the abdomen (code 74160) and a CT angiogram of the abdomen (code 74175) to have had one examination. We also collected data regarding the specialty of the physician ordering the examination and the diagnostic reason for the examination.

We defined early diagnosis of AAA as a patient with a time interval of greater than 6 months between the first imaging examination and the index procedure and late diagnosis as patients who underwent the index procedure within 6 months of the first imaging examination. We chose 6 months, as the follow-up interval reflected a decision to observe the patient after initial imaging but also conducted a sensitivity analysis using a definition of greater than 3 months as early diagnosis (Appendix, online only).

Other measures. Patient age, sex, race, and Medicaid status were recorded from denominator or beneficiary summary files. Patient residence was grouped into urban or rural areas using U.S. Department of Agriculture census-based Rural Urban Commuting Area (RUCA) codes.[6,7] Nonmetropolitan areas were defined as a population of less than 50,000 and included RUCA codes 4, 5, 6, 7, 7.2, 7.3, 7.4, 8, 8.2 8.3, 8.4, 9, 9.1, 9.2, 10, 10.2, 10.3, and 10.5. Metropolitan areas (population >50,000) included RUCA codes 1, 2, 3, 4.1, 7.1, 8.1, and 10.1.

Median household income from 2000 Census Bureau data was assigned to each beneficiary according to the recorded beneficiary residence zip code. Information on income was available for about 95% of Medicare beneficiaries. Income was not available for those with a zip code specific to a post office box or for those living in zip codes of less than 300 people. Beneficiaries with missing income information were excluded from subsequent analysis. Comorbidity was estimated using methods described by Elixhauser et al.[8] Hospitals were categorized by teaching status and yearly AAA repair volume. Hospital AAA repair volume was coded as a categorical variable by quintile. Hospitals in the lowest quintile were defined as low-volume hospitals, and those in the highest quintile were defined as high-volume hospitals.

Statistical analysis. The characteristics of patients with early vs late diagnosis and those undergoing repair for intact vs ruptured AAAs were analyzed with standard descriptive statistics: χ^2 for categorical variables and *t*-test for means. Multivariable logistic regression modeling was then used to determine independent predictors of early diagnosis. Standard errors of the coefficients were clustered at the hospital level to control for unobserved hospital characteristics such as differences in treatment patterns.

We controlled statistically for the patient's sex and age at the time of the index procedure; patient race (two categories: white, other); Medicaid eligibility during any of the calendar year of the repair; comorbid conditions during the study period; median household income according to the beneficiary's resident zip code, rural/urban classification of residence, yearly hospital AAA repair volume, and hospital teaching status. Dummy variables for year of repair were also included in the model to capture trends.

All hypothesis tests were done on a two-tailed basis with P values of $<.05$ considered significant. The lowest P value reported was $<.0001$. Statistical analyses were performed using SAS v. 9.1.3 (SAS Institute, Cary, NC) for data extraction and management and Stata v. 11.2 (StataCorp, College Station, Tex) for analysis.

RESULTS

A total of 14,948 patients underwent AAA repair during the study period, 13,738 (92%) of whom had repair for intact AAAs, whereas 1210 (8%) had repairs for ruptured AAAs. Mean age at repair was 77.5 ± 6.1, whereas mean age at first image was 75.1 ± 6.1. Men comprised 77% of the sample. Of the cohort, 95% were Caucasian, 71% lived in metropolitan areas, and 62% were cared for in a teaching hospital. Most patients (57%) were treated in a high-volume hospital (median estimated yearly AAA volume, 48 repairs/year), whereas only 2.1% were cared for in low-volume hospitals (median estimated yearly AAA volume, two repairs/year).

Early diagnosis was identified for 60.6% (62.9% for intact AAA, 35.1% of ruptured AAA) of patients receiving AAA repair, whereas 39.4% (37.1% for intact AAAs, 64.9% of ruptured AAAs) received prompt repair within 6 months of the first image (late diagnosis). Patients with early diagnosis received an average of 6.5 ± 3.5 images prior to repair, compared with 1.8 ± 0.9 preoperative images for patients with a late diagnosis. Mean follow-back was 39.0 ± 16 months for early diagnosis and 1.5 ± 1.4 months for late diagnosis ($P < .0001$). Comparisons of those with early and late diagnosis are summarized in Table I. Women were more likely than men to have repair after early diagnosis (66.3% vs 59.0%; $P < .0001$), as were those residing in metropolitan areas (61.8% vs 57.7%; $P < .0001$). Increasing hospital AAA volume was also associated with an increasing proportion of patients with early diagnosis ($P < .0001$).

From 2006 to 2009, there was a modest but steady decrease in the proportion of AAAs with late diagnosis (41.2% in 2006 to 36.6% in 2009; $P < .0001$) and a corresponding increase in AAA repairs after early diagnosis. The overall rate of AAA repair per 100,000 beneficiaries decreased over the same period as well 143 in 2006, 140 in 2007, 133 in 2008, and 126 in 2009. Other trends are shown in Table II.

The coded diagnosis for the earliest ordered image was AAA in 52.2% of patients with an intact AAA repair (50.1% with early diagnosis and 55.7% with late diagnosis). Other commonly listed diagnoses were abdominal pain (7.3%), renal pathology (7.0%), suspected gallstones (2.9%), splenomegaly (1.0%), prostate neoplasm (1.0%), and diverticulosis (1.0%). The proportion of those with AAAs as the listed diagnosis of the earliest image decreased over the course of the study (55.2% in 2006, 53.4% in 2007, 51.0% in 2008, and 48.6% in 2009; $P < .0001$).

Primary care providers (PCP)s ordered 51.0% of the earliest images for patients ultimately receiving repair for intact aneurysm. For those with a late diagnosis, PCPs accounted for 44.0% of first images. The trend for PCPs ordering the earliest image showed no change for those with early diagnosis, but for those with late diagnosis, the rate decreased over time (Table III). Ultrasound was more commonly the modality of the earliest examination for those with early compared with late diagnosis (57.4% vs 36.5%; $P < .0001$). These rates were unchanged over the course of the study period. Only 25.9% of those receiving AAA repair received an abdominal ultrasound with a diagnosis of AAA as the earliest image.

Table I. Characteristics of Medicare beneficiaries receiving AAA repair

	Early diagnosis (n = 9298)	*Late diagnosis (n = 6472)*	P *value*
Age at repair, years	78.0 ± 6.0	76.8± 6.1	<.0001
Sex			
Male	75.1	80.5	<.0001
Female	24.9	19.5	
Year			
2006	58.8	41.2	<.0001
2007	59.4	40.6	
2008	61.3	38.7	
2009	63.4	36.6	
Race			
White	60.6	39.3	.86
Other	60.3	39.6	
Residence			
Metropolitan	61.8	38.2	<.0001
Nonmetropolitan	57.7	42.3	
Hospital teaching status			
Yes	61.3	38.7	.05
No	59.7	40.3	
Medicaid eligible			
Yes	60.0	40.0	.66
No	60.7	39.3	
Hospital AAA volume			
Low	48.9	51.1	<.0001
Medium	58.9	41.1	
High	62.3	37.7	

AAA, Abdominal aortic aneurysm.

Table II. Yearly trends for AAA repairs, 2006-2009

Variable	*Total*	*2006*	*2007*	*2008*	*2009*	P *value*
Male, %	77.2	77.5	78.2	77.2	75.9	.15
Age, years	77.5	77.3	77.4	77.7	77.7	.004
Ruptured, %	8.1	8.5	8.1	8.0	7.7	.68
Early diagnosis, %	60.6	58.8	59.4	61.3	63.4	.0001
Metropolitan residence	70.7	71.4	71.5	69.6	70.2	.19
High-volume hospital, %	57.4	57.6	58.3	57.4	56.1	.29

AAA, Abdominal aortic aneurysm.

Table III. Yearly trends of first images (intact AAA repair)

	Total	*2006*	*2007*	*2008*	*2009*	P *value*
First image ordered by PCP, %	49.4	49.8	51.0	48.7	47.9	.05
Ultrasound examination, %	46.3	46.9	46.5	44.6	47.1	.13
AAA diagnosis, %	50.0	52.8	51.2	48.9	46.6	<.0001

AAA, Abdominal aortic aneurysm; *PCP,* primary care provider.

Table IV. Predictors of early diagnosis prior to AAA repair[a]

Variable	*OR*	*95% CI*	P *value*
Female sex	1.39	1.27-1.49	<.0001
Age (per decade)	1.41	1.32-1.72	<.0001
Presence of rupture	0.32	0.28-0.37	<.0001
Year			
2006	1.0	Referent	
2007	1.02	0.93-1.12	.63
2008	1.12	1.02-1.23	.02
2009	1.20	1.09-1.33	.0001
Caucasian race	1.06	0.89-1.23	.50
Income			
Low	0.97	0.85-1.10	.59
Middle	1.0	Referent	
High	1.06	0.98-1.15	.17
Hospital volume			
Low	0.82	0.64-1.04	.10
Mid	1.0	Referent	
High	1.12	1.03-1.21	.005
Medicaid-eligible	0.98	0.86-1.12	.79
Nonmetropolitan residence	0.89	0.82-0.96	.003
Teaching hospital	1.01	0.93-1.10	.79

AAA, Abdominal aortic aneurysm; *CI,* confidence interval; *OR,* odds ratio.
[a]Adjusted for patient comorbidity.

By multivariate analysis, early diagnosis was more likely for women, older patients, metropolitan residence, and intact repair (Table IV). Compared with 2006, repairs in 2008 (odds ratio, 1.12; 95% confidence interval, 1.02-1.23; $P = .02$) and 2009 (odds ratio, 1.20; 95% confidence interval, 1.09-1.33; $P = .0001$) were more likely to have had an early diagnosis.

Although intact repairs were more likely to be diagnosed early, we determined that 35.1% of patients undergoing repair for ruptured AAAs received abdominal CT scan or ultrasound greater than 6 months prior to surgery. An additional 4.9% obtained imaging 1 to 6 months prior to repair. Only 57.3% of patients had no abdominal imaging within 30 days prior to rupture. For patients with early diagnosis, those with rupture had fewer exams (median, 6 vs 5; $P < .0001$) but similar time intervals between the first image and the index procedure (39.3 vs 38.9 months; $P = .75$) compared with those receiving repair for intact AAAs.

DISCUSSION

In the U.S. between 2006 and 2009, approximately 40% of fee-for-service Medicare patients who had AAA repair underwent repair within 6 months of their first abdominal imaging. This contrasts with previous studies of well-screened populations for which only 10% to 12% of newly diagnosed AAAs undergo repair.[3,4] The substantially higher rate of repair in a short interval following the first image suggests that screening is underutilized in the Medicare population.

Recent national efforts to improve insurance coverage for screening include the Screen Abdominal Aortic Aneurysms Very Efficiently (SAAAVE) Act, which has provided expanded coverage for screening in Medicare since 2007. However, the SAAAVE Act appears to have accounted for only a modest increase in abdominal ultrasound examinations, and only about 15% of those at risk based on smoking history received screening examinations in 2009.[5] The limited impact of the SAAAVE act may in part be due to the narrowly defined requirements of coverage. Patients must receive the ultrasound examination within the first year of Medicare eligibility, and reimbursement is allowed only if it is tied to the Welcome to Medicare examination. Furthermore, unlike screening programs in the United Kingdom and Europe for which patients receive a written invitation to obtain a screening examination, in the U.S., patients must rely on the primary care provider to order the test when indicated.

Based on changes that would be expected if the SAAAVE Act had been widely adopted after its implementation in 2007, our findings support the conclusion that our study population was poorly screened. Repair rates did not increase over the study period, which would be expected if screening rates had increased.[9] Conversely, the proportion of primary care providers ordering first examinations for those with late diagnosis decreased over the study period, as did the proportion of first images with a diagnosis of AAA and the proportion of first images that were ultrasounds. These findings together suggest that a larger proportion of AAAs continue to be diagnosed incidentally rather than as a direct result of an organized screening program. As such, many who would benefit from screening remain undiagnosed and at risk for rupture.

Women in our study were found to be more likely to undergo repair after early diagnosis. This may reflect that women may be more likely to receive preventative medical care and are therefore more likely to have received abdominal imaging.[10,11] In addition, women may be more likely to be imaged for a family history or for other unrelated abdominal symptoms. Conversely, women may get less timely treatment care and have to wait longer until they get AAA repair. Sex differences in timeliness of treatment have been described for lung cancer, although it was not known if the observed differences were due to differing rates of refusal or some other reason.[12]

The finding that many AAA repairs were performed soon after the first imaging examination may also reflect a patient or surgeon preference to repair AAAs at smaller diameters in the U.S. compared with other countries. An observational study of 10,228 patients undergoing endovascular AAA repair in the U.S. demonstrated a mean AAA diameter of 5.48 cm; 59.4% had an AAA diameter of less than 5.5 cm[13] at the time of repair. However, since it was not uncommon to have the aneurysm measured for repair prior to meeting size criteria for repair and because the interval between the preoperative measurements and the repair was unknown, no conclusions can be made regarding the size of the aneurysm at the time of repair. In addition, although repair of small AAAs may be prevalent, it most likely does not completely explain the high rate of early repairs. Based on estimations of well-screened populations, if we assumed in our study all patients with AAAs greater 4.4 cm had been offered early repair, then approximately 25% would have received repair after first diagnosis,[4] leaving an additional 15% in our study unaccounted for.

Of particular concern was the observation that 35.1% of patients with ruptured AAAs had received diagnostic imaging at least 6 months prior to repair. Although the goal of early diagnosis is to prevent rupture, other factors may be contributory in preventing timely treatment. Some may have had other conditions that required treatment and delayed treatment of the AAA. Others may have declined surgery prior to rupture or been lost to surveillance follow-up. For others, AAA rupture may have occurred at small diameters. As the risk of rupture of AAAs 4.5 to 5.4 cm in diameter is approximately 1.4% per year[14,15] suggesting that rupture of small AAAs would account for only a small proportion of ruptured AAAs. Finally, the interval between the first image and rupture may have been long enough that the AAA may not have been present on the earliest examination. In our study, however, only 14.3% of those ruptured had a 3- or 4-year interval between most recent image and rupture, and no patient had longer than a 4-year interval, making this explanation unlikely.

Our study is subject to certain limitations. As with all studies involving administrative data, we were unable to collect clinical information such as aneurysm size, which would have provided additional information for our analysis. Furthermore, interpretation is subject to errors or variability in coding, such as differential coding of comorbidities associated with different discharge status and inability to distinguish the imaging diagnosis code as a pre- or postimaging diagnosis.[16] However, these errors are less likely for hospitalizations of serious medical conditions or requiring major surgical procedures.[17,18] We believe, therefore, that these limitations do not detract from our primary conclusions.

In summary, we have shown that despite some advances in screening practices, significant missed opportunities still exist in the U.S. Medicare population for regarding AAA care. It remains common for beneficiaries to undergo AAA repair soon after initial imaging, suggesting that many AAAs are diagnosed incidentally rather than as a direct result of improved screening. Conversely, a significant proportion of patients with early imaging ruptured prior to repair. Both findings warrant further study to evaluate the clinical factors associated with late AAA diagnosis, as well as the adherence to surveillance standards for those diagnosed early.

AUTHOR CONTRIBUTIONS

Conception and design: MW, MH, LB
Analysis and interpretation: MW
Data collection: MW, LB
Writing the article: MW
Critical revision of the article: MH, JS, RD, LB
Final approval of the article: MW, MH, JS, RD, LB
Statistical analysis: MW, LB
Obtained funding: MW, MH, LB
Overall responsibility: MW

REFERENCES

1. Lindholt JS, Norman PE. Meta-analysis of postoperative mortality after elective repair of abdominal aortic aneurysms detected by screening. Br J Surg 2011;98:619-22.
2. Screening for abdominal aortic aneurysm: recommendation statement. Ann Intern Med 2005;142:198-202.
3. Ashton HA, Buxton MJ, Day NE, Kim LG, Marteau TM, Scott RA, et al. The Multicentre Aneurysm Screening Study (MASS) into the effect of abdominal aortic aneurysm screening on mortality in men: a randomised controlled trial. Lancet 2002;360:1531-9.
4. Darwood R, Earnshaw JJ, Turton G, Shaw E, Whyman M, Poskitt K, et al. Twenty-year review of abdominal aortic aneurysm screening in men in the county of Gloucestershire, United Kingdom. J Vasc Surg 2012;56:8-13.
5. Shreibati JB, Baker LC, Hlatky MA, Mell MW. Impact of the Screening Abdominal Aortic Aneurysms Very Efficiently (SAAAVE) Act on Abdominal Ultrasound Use Among Medicare Beneficiaries. Arch Intern Med 2012;172:1456-62.
6. Economic Research Service. Measuring Rurality: Rural-Urban Commuting Area Codes. Washington, DC: United States Department of Agriculture - Economic Research Service; 2005 [cited 2011 Nov 12]; Available at: http://www.ers.usda.gov/briefing/Rurality/RuralUrbanCommutingAreas/. Accessed August 1, 2012.
7. Washington State Department of Health. Guidelines for using rural-urban classification systems for public health assessment: A four-tier consolidation of the RUCA system at the sub-county level. Olympia, WA: Washington State Department of Health; 2009 [cited November 12, 2011]; Available at: http://www.doh.wa.gov/data/Guidelines/RuralUrban2.htm#fourtier.
8. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care 1998;36:8-27.
9. Kim LG, RA PS, Ashton HA, Thompson SG. A sustained mortality benefit from screening for abdominal aortic aneurysm. Ann Intern Med 2007;146:699-706.
10. Bertakis KD, Azari R, Helms LJ, Callahan EJ, Robbins JA. Gender differences in the utilization of health care services. J Fam Pract 2000;49:147-52.
11. Briscoe ME. Why do people go to the doctor? Sex differences in the correlates of GP consultation. Soc Sci Med 1987;25:507-13.
12. Shugarman LR, Mack K, Sorbero ME, Tian H, Jain AK, Ashwood JS, et al. Race and sex differences in the receipt of timely and appropriate lung cancer treatment. Med Care 2009;47:774-81.
13. Schanzer A, Greenberg RK, Hevelone N, Robinson WP, Eslami MH, Goldberg RJ, et al. Predictors of abdominal aortic aneurysm sac enlargement after endovascular repair. Circulation 2011;123:2848-55.
14. Long-term outcomes of immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346:1445-52.
15. Lederle FA, Wilson SE, Johnson GR, Reinke DB, Littooy FN, Acher CW, et al. Immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346:1437-44.
16. Finlayson EV, Birkmeyer JD, Stukel TA, Siewers AE, Lucas FL, Wennberg DE. Adjusting surgical mortality rates for patient comorbidities: more harm than good? Surgery 2002;132:787-94.
17. Kiyota Y, Schneeweiss S, Glynn RJ, Cannuscio CC, Avorn J, Solomon DH. Accuracy of Medicare claims-based diagnosis of acute myocardial infarction: estimating positive predictive value on the basis of review of hospital records. Am Heart J 2004;148:99-104.
18. Quan H, Parsons GA, Ghali WA. Validity of procedure codes in International Classification of Diseases, 9th revision, clinical modification administrative data. Med Care 2004;42:801-9.

Submitted Oct 24, 2012; accepted Dec 9, 2012.

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APPENDIX (online only).

We performed a sensitivity analysis defining early diagnosis as greater than 3 months between first image and surgery. With this definition, 66.5% (9942/14948) of the cohort received an early diagnosis prior to surgery. Multivariate analysis with early diagnosis defined as first image at least 3 months prior to surgery is shown below.

Supplementary Table (online only). Predictors of early diagnosis prior to AAA repair[a]

Variable	*OR*	*95% CI*	P *value*
Female sex	1.36	1.24-1.50	<.0001
Age (per decade)	1.33	1.24-1.42	<.0001
Presence of rupture	0.30	0.26-0.35	<.0001
Year			
2006	1.0	Referent	
2007	1.02	0.93-1.14	.55
2008	1.11	1.00-1.23	.05
2009	1.11	1.00-1.23	.04
Caucasian race	0.94	0.78-1.14	.54
Income			
Low	1.01	0.89-1.16	.81
Middle	1.0	Referent	
High	1.04	0.95-1.14	.37
Hospital volume			
Low	0.95	0.74-1.24	.73
Mid	1.0	Referent	
High	1.09	1.00-1.18	.05
Medicaid-eligible	1.03	0.90-1.19	.66
Nonmetropolitan residence	0.86	0.79-0.94	.001
Teaching hospital	1.02	0.94-1.11	.61

AAA, Abdominal aortic aneurysm; *CI,* confidence interval; *OR,* odds ratio.
[a]Adjusted for patient comorbidity.