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Original Research

Methodology for the evaluation of vascular surgery manpower in France

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SUMMARY

Objectives: The French population is growing and ageing. It is expected to increase by 2.7% by 2020, and the number of individuals over 65 years of age is expected to increase by 3.3 million, a 33% increase, between 2005 and 2020. As the number of vascular surgery procedures is closely associated with the age of a population, it is anticipated that there will be a significant increase in the workload of vascular surgeons.

Study design: A model is presented to predict changes in vascular surgery activity according to population ageing, including other parameters that could affect workload evolution.

Methods: Three types of arterial procedures were studied: infrarenal abdominal aortic aneurysm (AAA) surgery, peripheral arterial occlusive disease (PAOD) procedures and carotid artery (CEA) procedures. Data were selected and extracted from the national PMSI (Medical Information System Program) database. Data obtained from 2000 were used to predict data based on an ageing population for 2008. From this model, a weighted index was defined for each group by comparing expected and observed workloads.

Results: According to the model, over this 8-year period, there was an overall increase in vascular procedures of 52.2%, with an increase of 89% in PAOD procedures. Between 2000 and 2009, the total increase was 58.0%, with 3.9% for AAA procedures, 101.7% for PAOD procedures and 13.2% for CEA procedures. The weighted model based on an ageing population and corrected by a weighted factor predicted this increase.

Conclusion: This weighted model is able to predict the workload of vascular surgeons over the coming years. An ageing population and other factors could result in a significant increase in demand for vascular surgical services.

Introduction

In France, many vascular surgeons will retire over the next 10 years, and the risk that they will not be replaced has raised the issue of predicting future activity in this discipline.[1,2] The French population is growing and ageing.

According to the French National Institute for Statistics and Economic Studies (INSEE), the French population will increase by 1.4% by 2015 and by 2.7% by 2020.[3] The fastest growing segment of the population is individuals over 65 years of age; this age group is expected to increase by 3.3 million (33%) between 2005 and 2020. The ageing index, or the

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proportion of the population over 65 years of age compared with those under 20 years of age, was 71% in 2010 and is expected to increase to 94% by 2020.

Two main factors are responsible for these forecasts. First, people are living longer; life expectancy has increased from 66.7 years for individuals born in 1946 to 76.1 years for those born in 1996. Second, the 'baby boomers' correspond to a wave of population density that will begin to hit retirement age in 2011.

Basic statistics have shown that vascular surgery is primarily performed in elderly patients. Therefore, it can be hypothesized that the workload of vascular surgeons will increase over the next two decades, largely due to the ageing of the French population; however, the extent of this increase is not known. To answer this question, the authors developed a methodology to estimate the number of surgical procedures to be performed in France over the coming years by considering current activity together with demographic changes and an ageing population.

It is recognized that other factors, including technological innovations or political decisions from care holders, could influence the use of vascular surgical services and the need for vascular surgeons. As such, the authors sought to integrate some of these factors into the forecasts. Finally, the results were compared with the annual statistics obtained by the State in order to evaluate the impact of these factors and the accuracy of the model.

Methods

Three types of arterial procedures were studied: infrarenal abdominal aortic aneurysm (AAA) procedures, peripheral arterial occlusive disease (PAOD) procedures and carotid artery (CEA) procedures. Data were extracted from the State Medical Information System Program (PMSI) database, available for 2000 and 2008.

The year 2000 was selected as effective exhaustive coding has been available since that date. The year 2008 was selected in order to have a sufficiently long period of time to validate the predictions. Changes in the classification coding of medical acts in France between 2000 and 2008 meant that the coding system in use in 2000 [Classification of Medical Acts (CDAM)] had to be adapted to fit the current Common Classification of Medical Acts (CCAM) in use in 2008. Code matching between the two classifications was comprehensive. The CCAM includes more codes to specify the same acts as CDAM.

Twenty-nine CDAM codes were selected for 2000 (seven for AAA procedures, 14 for PAOD procedures and eight for CEA procedures), and these were matched with 59 CCAM codes for 2008 (20 for AAA procedures, 22 for PAOD procedures and 17 for CEA procedures) (see Appendix).

The 'effective requirement' for vascular surgery among the population of mainland France for 2000 (T0) was identified from the PMSI database. Data were provided by the French Technical Agency for Hospital Information. A prediction model was established for the three types of procedures based on the age of the population in 2008 (T1). This prediction was prepared using the OMPHALE method developed by INSEE and described elsewhere.[4] Initial projections were carried out by INSEE in 1965, with the aim of calculating future school enrolment.

The OMPHALE method is a complex application that includes a theoretical projection of population, population databases, demographic analysis techniques and tools for building scenarios for the future. Projections are based on the 'components method'. This consists of performing an age distribution based on follow-up of three components: births, deaths and migration.

The OMPHALE method allows projections to be updated continuously by integrating the various censuses, including flows observed by origin and destination. With this method, which is only based on the population, projections are performed on any spatial entity of over 50,000 inhabitants.

Practically, projection to the time horizon T1 of the inhabitants of a territory is calculated from the numbers by sex and age at time T0. Four elements are taken into account for each spatial entity: ageing of individuals by 1 year, addition of births in the year, subtraction of deaths during the year, and addition of net migration.

To be as accurate as possible, these projections were made at 186 specific basins (spatial entity). The construction of these entities is based on the spatial practice of patients by flow analysis from home to hospital. The predictions of vascular surgical workload are realized from the resident population of such entities. Finally, all these local projections were aggregated to obtain the national result.[5] The activity identified for the T1 model was obtained by standardization of the acts according to the age and sex of the population observed at T0, according to the last population census.

The expected modelling of hospital activity at T1 for a spatial entity was expressed as:

$$\text{Exp } T1 = \sum_{k}^{1} P1(T_{iT0})$$

where Exp T1 is the expected hospital activity at T1 for a spatial entity, k is the age group for men and women in the spatial entity, P1 is the population level for k at T1, and T_{iT0} is the rate of each case-mix group according to the age group of men and women in the spatial entity.

Using this approach, the model only relies on the ageing population according to the hypothesis that all other factors are equal. However, the ageing population cannot be the only criterion for the workload evolution. In order to integrate other factors into the model, the expected results found using the model from 2000 to 2008 were compared with the crude numbers observed in 2008 in order to calculate a weighted index. This index represents the differential related to other factors influencing the workload of vascular surgeons. The obtained weighted index was then integrated in the model for 2009, and the calculated and observed data for this period were compared.

Statistical analysis

The comparison between the predictive model and observed surgical workload for 2009 was established using linear regression analysis without constant with JMP software. The coefficients of proportionality and their 95% confidence intervals were calculated. Accuracy of these coefficients has been validated previously by calculating the t ratio and standard error. As shown elsewhere, linear regression close to a value of '1', within 5%, was used to validate the weighted model.[6]

Results

In France, the population is growing and ageing. Growth of 3.1% was observed between 2000 and 2009, and national statistics predict a further increase of 2.8 million people (4.4%) by 2030. At the same time, the number of people over 64 years of age increased by 8.7% between 2000 and 2009, and this trend is expected to continue with an additional 5.6 million people (55.4%) by 2030 (Fig. 1).

The predictive model, for 2008, forecasted a total of 62,670 vascular procedures for the three groups, corresponding to a total increase of 14.8% over 8 years, with an increase of 12.9% for AAA procedures, 15% for PAOD procedures and 15.2% for CEA procedures. In comparison, for the same year, the PMSI database recorded 83,123 vascular surgical procedures, corresponding to a 52.2% increase in 8 years (Table 1). A detailed analysis of this finding showed almost a two-fold increase in PAOD procedures compared with 2000, with a moderate increase for CEA procedures (14.2%) and AAA procedures (0.5%).

Comparing these numbers, it appears that the prediction based on ageing alone overestimated the number of CEA procedures by 16% and AAA procedures by 17%. In contrast, the number of PAOD procedures was underestimated by 61%.

Weighted indices were 0.89 for AAA procedures, 1.64 for PAOD procedures and 0.99 for CEA procedures. Using these weighted indices, the number of procedures for 2009 was estimated (Table 2). There was a difference of 2662 procedures (3.1%) between the observed and weighted expected workload. 95% confidence intervals (CI) of the 'coefficients of proportionality' between the activity in 2009 and expected weighted activity observed in 2009, estimated by the linear regression line, were 0.99–1.02 for AAA, 1.03–1.05 for PAOD and 0.97–0.99 for CEA; these were well matched with the theoretical value of 1, demonstrating the accuracy of the weighted model. Forecasted increases in the workload of vascular surgeons are represented for each group in Fig. 2, and show how the adjusted model seems to predict the future evolution.

The procedures were also analysed in detail by age group for 2009, showing that 70.3% of procedures were performed in patients over 64 years of age (Table 3).

Finally, the increase in vascular procedures was forecasted to be 54.9% between 2000 and 2009, close to the crude statistics showing a 59.8% increase over the same time period, with a variable increase depending on the type of surgery: 3.9% for AAA procedures, 101.7% for PAOD procedures and 13.2% for CEA procedures.

Discussion

To the authors' knowledge, this is the first study to use a mathematical model to predict long-term evolution of the workload of vascular surgeons. This model, which relies on tested and previously published tools,[7,8] has been adapted from validated national forecasts established by INSEE, and is based on ageing as a major factor influencing the number of arterial procedures. Unlike prior forecasts, the methods used in this study are based on established patterns of surgical practice. The authors believe that this approach is valid to predict the impact of a population shift on workload. This method has some limitations as it assumes that the age-specific profile of surgical demand will remain constant, and this may not be the case. Despite this potential limitation, the model was able to forecast the trend of vascular workload over recent years.

As a consequence of ageing of the French population, it is predicted that the increase in the use of vascular surgical

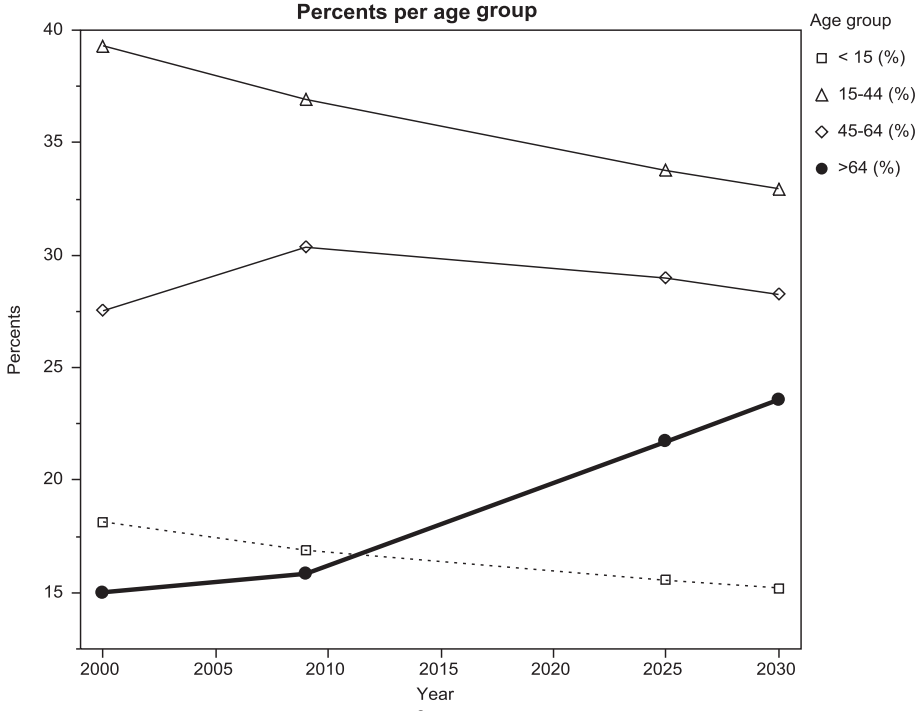

Fig. 1 – Predicted variation in the French population (y axis) for each age group from 2000 to 2030.

Table 1 – Variation in expected and observed procedures between 2000 and 2008 (mainland France).

Groups	AAA	PAOD	CEA	Total
2000 observed	8741	29,643	16,234	54,618
2008 observed	8787	55,979	18,357	83,123
2008 expected	9865	34,101	18,704	62,670
Expected variation (%)[a]	12.9	15.0	15.2	14.7
Observed variation (%)[b]	0.5	88.8	14.2	52.2
Weighted index[c] (2000–2008)	0.89	1.64	0.99	

Reference: ATIH–PMSI 2008 & 2009 – expected model.
AAA, infrarenal abdominal aortic aneurysm surgery; PAOD, peripheral arterial occlusive disease procedures; CEA, carotid artery procedures.
a Difference between 2008 expected and 2000 observed acts, in percentage.
b Difference between 2008 and 2000 observed acts, in percentage.
c (Difference between 2008 observed and 2008 expected acts/2008 expected acts) + 1.

services will considerably exceed the rate of overall population growth. However, the workload prediction based on the ageing population alone is a poor reflection of the actual figures, which should include other factors such as the impact of evolving technology on the practice of vascular surgery.

For the PAOD group, the underestimation is likely to be due to the growing number of endovascular treatments, which allows patients who were unsuitable for conventional surgery to receive treatment. This has led to a sharp increase in the number of procedures. In contrast, the initial model overestimated the number of CEA and AAA procedures; the reason for this is not known, but may be due to evolution of medical treatment (statins) and better control of cardiovascular risks, with stabilization of the incidence and progression of these lesions in the general population.

The integration of a weighted index that reflects actual surgical practice is the best, if not the only, possibility to take all other factors into account. This may affect (strongly for some) the evolution of the surgical workload.

Continued technological advances may lead to the application of less invasive procedures to a wider range of individuals. Minimally invasive surgical techniques are rapidly improving with new applications. This trend is demonstrated by PAOD surgery, with a dramatic increase in workload. As a result, a large number of old and frail patients presenting with several comorbidities can now be treated using endovascular procedures under local anaesthesia,[9,10] partially explaining the increasing number of procedures. Interestingly, the PAOD group seems to be the only group for which endovascular procedures occur in addition to surgical procedures. In the other groups, endovascular procedures have replaced some open procedures, but the total number of procedures has remained fairly stable.

Concerning PAOD procedures, it may be true that some vascular surgeons have experienced demand for a new technology, but there is also a real opportunity for some elderly patients with chronic critical ischaemia, unfit for open surgery, who can now be treated under local anaesthesia using endovascular techniques. Further epidemiological studies are needed to determine if there are changes in PAOD procedures other than those related to ageing of the French population. One factor could be the increasing incidence of diabetes in Western countries, including France. As an example, in the USA, diabetes increased by 52% from 1997 to 2003.[11,12]

In contrast, although a significant change has been observed in the treatment of AAA in recent years, with an increase in the number of endovascular repairs (EVAR), the total number of patients undergoing an AAA procedure remains relatively stable. As shown by Dillavou *et al.*, EVAR is replacing open AAA surgery in many cases but without an overall increase in case volume.[13] Surgical guidelines issued by randomized studies for AAA explain this relative stability. Treatment for AAA, regardless of the technique used, is only recommended for aortic aneurysms with a diameter over 50–55 mm, hence limiting the number of procedures.[14,15]

For carotid surgery, following EVA-3S and SPACE studies, carotid artery stenting (CAS) has not replaced conventional surgery. CAS has only had a limited impact in France for some interventions and in some high-risk symptomatic patients, and this marginal trend has not affected the total number of carotid procedures.[16,17]

Several studies are consistent with these results. In 2003, Etzioni *et al.* showed that ageing in the US population will, in the near future, result in significant increases in demand for surgical services.[18] The main question remains: how will national healthcare services, care providers and vascular surgeons handle the impending increase in procedures generated by the ageing French population? The probable answer is an increase in the number of practising vascular surgeons, but this long-term solution also needs to consider the need for training and educating young surgeons.[19,20] In France, it takes 15 years to train a fully operational vascular surgeon from the onset of his/her medical studies.[21]

Table 2 – Evaluation of weighted model in mainland France, 2009.

Groups	2009 Expected and weighting[a]	2009 Observed	Variation	Coef (with Y = 0)[b]	*t*-ratio	Prob > |t|
AAA	8918	9084	+1.9%	1.02	80.65	<0.001
PAOD	56,882	59,814	+5.1%	1.04	178.6	<0.001
CEA	18,814	18,378	−2.3%	0.98	121.03	<0.001
Total	84,614	87,276	+3.1%			

Reference: ATIH–PMSI 2009 & expected model.
AAA, infrarenal abdominal aortic aneurysm surgery; PAOD, peripheral arterial occlusive disease procedures; CEA, carotid artery procedures.
a 2009 expected acts with application of the weight index.
b Coefficient of proportionality without constant.

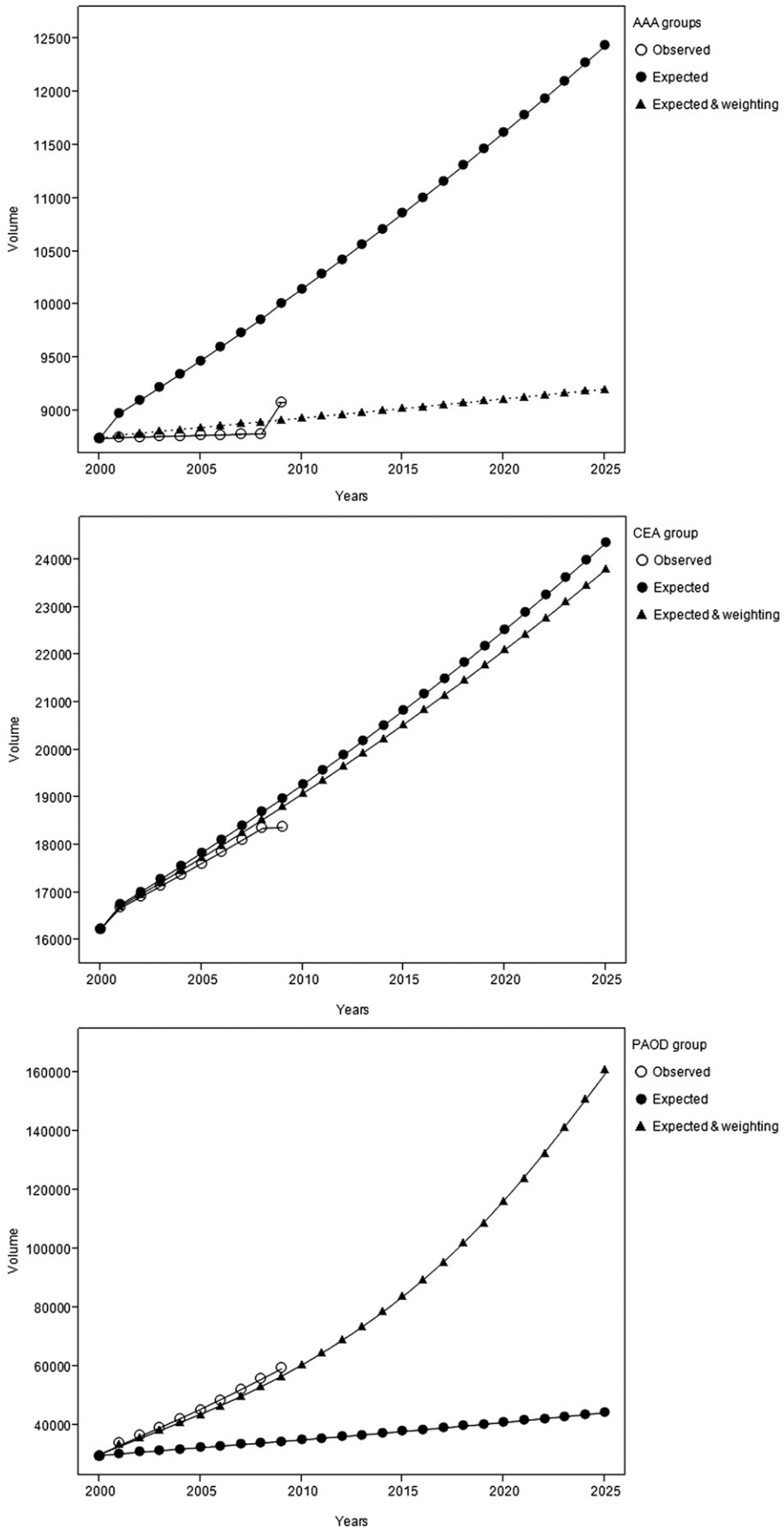

Fig. 2 – Comparison of the observed, expected, and expected and weighted number of procedures for each type of surgery [infrarenal abdominal aortic aneurysm surgery (AAA), peripheral arterial occlusive disease (PAOD) procedures and carotid artery (CEA) procedures] from 2000 to 2025.

Table 3 – Observed procedures by age in mainland France, 2009.

Years	AAA	PAOD	CEA	Total
<15	0	10 (0.01%)	1	11 (0.01%)
15–44	58 (0.6%)	1008 (1.7%)	98 (0.5%)	1164 (1.35%)
45–64	2131 (23.5%)	18,316 (30.6%)	4282 (23.3%)	24,729 (28.35%)
>64	6895 (75.9%)	40,480 (67.7%)	13,999 (76.2%)	61,374 (70.3%)
Total in France	9084	59,814	18,380	87,278

AAA, infrarenal abdominal aortic aneurysm surgery; PAOD, peripheral arterial occlusive disease procedures; CEA, carotid artery procedures. Vascular surgery workload in 2009 by age and group (volume and percentage) for each group.

Some economists disagree with these predictions, and consider the prospect of training more medical specialists to be a risky move that will increase costs with no obvious improvement in health care.[22,23] Escarce found that regions with higher concentrations of surgeons have a higher rate of clinical work with a more costly diagnostic approach, but with no significant increase in therapeutic procedures.[24] However, it is not clear if increasing the number of vascular surgeons will result in an increase in the number of unnecessary procedures. The simplest solution to address the increasing workload in vascular surgery would be to ask surgeons to work more hours. However, significant changes in physicians' practice patterns, such as: feminization; demands for better quality of life; working time restrictions; Social security deficits; judiciarization have occurred over the last 20 years which may make this 'easy solution' inapplicable. It is also true that some improvements in surgical productivity could be made in France by lowering the burden of administrative paperwork, but given the circumstances, Breslin *et al*. were not too optimistic in the ability of surgeons to greatly increase their productivity.[25]

Conclusions

This study presented a reliable model to predict the workload of vascular surgeons in the forthcoming years to help surgeons and healthcare providers anticipate this problem. The aging population and technological innovations have resulted in a two-fold increase in the demand for vascular surgery over the last 10 years, and according to the model, this trend will continue to increase with a need for future research and changes in patient education, surgical education and practice.

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Competing interests

None declared.

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Appendix. Corresponding codes between French [Classification of Medical Acts (CDAM) and Common Classification of Medical Acts (CCAM)] and American [Current Procedural Terminology (CPT)] systems for the three groups.

	CDAM	CCAM	CPT
AAA	K672, K673, K674, K675, K676, K680, K681	DHKA 004, DGLF 001, DGLF 002, DGLF 005, DGPA 001, DGPA 005, DGPA 008, DGPA 010, DGPA 012, DGPA 013, DGPA 016, DGPA 017, DGPA 018, DGSA 001, DGSA 002, DGSA 004, EDLF 004, EDLF 005, EDPA 001, EDPA 005	34800, 34802, 34803, 34804, 34805, 34825, 34826, 34830, 34831, 34832, 34900, 35081, 35082, 35102, 35103, 35131, 35132
PAOD	K677, K678, K679, K751, K755, K758, K759, K760, K761, K762, K763, K764, K765, K766	EDCA 003, EDCA 004, EDCA 005, EEAF 001, EEAF 003, EEAF 004, EEAF 005, EEAF 006, EECA 001, EECA 002, EECA 003, EECA 005, EECA 006, EECA 007, EECA 008, EECA 010, EECA 012, EEFA 001, EEFA 003, EEGA 002, EEPF 001, EEPF 002	35141, 35142, 35151, 35226, 35256, 35286, 35355, 35371, 35372, 35381, 35454, 35456, 35459, 35470, 35473, 35474, 35521, 35533, 35556, 35558, 35565, 35566, 35571, 35583, 35585, 35587, 35621, 35623, 35654, 35656, 35661, 35665, 35666, 35671, 35700
CEA	K570, K571, K572, K573, K574, K575, K576, K579	EBAA 002, EBAF 001, EBAF 003, EBAF 009, EBAF 011, EBCA 002, EBFA 002, EBFA 006, EBFA 008, EBFA 009, EBFA 012, EBFA 014, EBFA 015, EBFA 016, EBFA 019, EBKA 002, EBKA 004	35301, 35390, 35458, 35475, 35501, 35601

AAA, infrarenal abdominal aortic aneurysm surgery; PAOD, peripheral arterial occlusive disease procedures; CEA, carotid artery procedures (CEA).