The Dutch Audit of Carotid Interventions

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The Dutch Audit of Carotid Interventions: Transparency in Quality of Carotid Endarterectomy in Symptomatic Patients in the Netherlands☆

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WHAT THIS PAPER ADDS

This paper provides transparency on the quality of carotid endarterectomy in patients with a symptomatic carotid stenosis in the Netherlands. Additionally, it could be used for international comparisons of quality of care and may be an incentive for other countries to establish a similar audit or could encourage harmonisation of existing national audits.

Background: The Dutch Audit for Carotid Interventions (DACI) registers all patients undergoing interventions for carotid artery stenosis in the Netherlands. This study describes the design of the DACI and results of patients with a symptomatic stenosis undergoing carotid endarterectomy (CEA). It aimed to evaluate variation between hospitals in process of care and (adjusted) outcomes, as well as predictors of major stroke/death after CEA.

Methods: All patients with a symptomatic stenosis, who underwent CEA and were registered in the DACI between 2014 and 2016 were included in this cohort. Descriptive analyses of patient characteristics, process of care, and outcomes were performed. Casemix adjusted hospital procedural outcomes as (30 day/in hospital) mortality, stroke/death, and major stroke/death, were compared with the national mean. A multivariable logistic regression model (backward elimination at $p > 0.10$) was used to identify predictors of major stroke/death.

Results: A total of 6459 patients, registered by 52 hospitals, were included. The majority (4,832, 75%) were treated <2 weeks after their first hospital consultation, varying from 40% to 93% between hospitals. Mortality, stroke/death, and major stroke/death were, respectively, 1.1%, 3.6%, and 1.8%. Adjusted major stroke/death rates for hospital comparison varied between 0 and 6.5%. Nine hospitals performed significantly better, none performed significantly worse. Predictors of major stroke/death were sex, age, pulmonary disease, presenting neurological symptoms, and peri-operative shunt.

Conclusion: CEA in The Netherlands is associated with an overall low mortality and (major) stroke/death rate. Whereas the indicator time to intervention varied between hospitals, mortality and (major) stroke/death were not significantly distinctive enough to identify worse practices and therefore were unsuitable for hospital comparison in the Dutch setting. Additionally, predictors of major stroke/death at population level could be identified.

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INTRODUCTION

In patients with a recent transient ischaemic attack (TIA) or ischaemic stroke in the presence of a high grade ipsilateral carotid artery stenosis, recurrent stroke can be best prevented by carotid endarterectomy (CEA).[1] Optimal care for patients undergoing carotid artery surgery is summarised in guidelines, based on large randomised controlled trials.[1–4] However, actual daily practice is not always consistent with these guidelines, allowing practice and patient outcomes to vary between healthcare providers.[5] This variation could indicate a difference in the quality of care at a national level.

The increasing demand for quality control methods and the introduction of a minimum threshold on hospital volume of 20 CEA per year in The Netherlands has led to the initiation of the Dutch Audit for Carotid Interventions (DACI).[6] This nationwide audit was initiated in 2012 and since June 2013 has been mandatory for all vascular surgeons performing carotid artery interventions. The main objective of this audit was to measure and improve quality of care in carotid artery interventions in The Netherlands. By registering important parameters on process of care and patient outcomes, a comparison of hospitals can be made and surgeons can be provided with benchmarked information on their quality of care. Providing insight into possible variation between hospitals can subsequently incite quality improvement. Additionally, information from the DACI can be used to monitor national guideline adherence and outcomes in patients undergoing carotid interventions.

This report describes the design of the DACI and provides an overview of the results of patients with a symptomatic carotid artery stenosis undergoing CEA in The Netherlands in the first years of the audit. The aim of this study was to report variation between hospitals in processes of care and (adjusted) patient outcome, as well as to identify independent predictors of major stroke and/or death related to CEA.

METHODS

DICA

The DACI is facilitated by the Dutch Institute for Clinical Auditing (DICA).[6] The DICA facilitates and organises the initiation of nationwide audits for various medical professions and offers a uniform format. In collaboration with DICA, the Dutch Society for Vascular Surgery initiated the Dutch Audit for Carotid Interventions (DACI). The DACI is overseen by a scientific committee, which is responsible for interpretation and accountability of the data.

DACI data source

Since June 2013, the DACI has been mandatory for all vascular surgeons and registers all patients undergoing a carotid intervention for a high grade carotid artery stenosis in the Netherlands. This includes CEA with or without patch angioplasty, eversion CEA, or carotid artery stenting (CAS). Each registered patient is scored on 77 items, grouped into three categories (Appendix 1). The first category includes patient characteristics and clinical presentation required to enable an adjusted comparison of data between hospitals. The second category includes items regarding the process of care and surgical treatment. The post-operative period and patient outcomes (30 day/in hospital) are registered in the third category. The data are prospectively collected via a web based survey or provided by the hospitals via a batch data file. Hospitals may decide who registers the data (e.g. data managers, nurse practitioners, or physicians). However, in all participating hospitals the final responsibility for registration of patients lies with the physician. The content of the dataset is evaluated on an annual basis and, if necessary, alterations are made. Verification of the DACI data was carried out in 2015 by a trusted third party. The process of verification was coordinated by an independent data verification committee, which consisted of medical experts, a biostatistician, a deputy of the Dutch Health Care Inspectorate, and a deputy from the Dutch patient federation. Data were verified through a random sample of 15 hospitals, and this will be continuously repeated in the future.

Patient selection

All patients undergoing CEA for a symptomatic stenosis and registered in the DACI between January 2014 and December 2016 were included. Date of birth, date of surgery, type of surgical procedure performed, and patient survival status (30 day/in hospital) had to be known to consider a patient eligible for further analysis. In The Netherlands, asymptomatic patients usually do not receive surgical intervention outside the confines of randomised clinical trials and CAS is not performed as standard primary treatment for a symptomatic carotid stenosis, therefore asymptomatic patients and patients treated by CAS were excluded. Additionally, patients treated in a hospital that stopped performing CEAs during the first year of the study were also excluded.

Definitions

Within the DACI, time to intervention was defined as the time from first consultation at the hospital to CEA, instead of the time from first neurological symptoms to intervention, because this is the timeframe that hospitals can influence themselves and can improve. Post-operative mortality was defined as mortality within 30 days after CEA and/or during the primary admission (30 day/in hospital). A post-operative stroke was described as a new neurological deficit 30 day/in hospital, which lasted longer than 24 h. A stroke resulting in a decline of more than 2 points in post-operative modified Rankin Scale (mRS) was considered as a major stroke, all others as minor strokes.[7,8] The combined outcome parameters stroke and/or death (stroke/death) and major stroke and/or death (major stroke/death) consisted of the patients who had a (major) stroke and/or death 30 day/in hospital. Cranial nerve injury (CNI) was defined as the loss of function of a cranial nerve, measured as 30 day/in hospital. Only a post-operative wound

haemorrhage that required a re-intervention was considered as a post-operative wound haemorrhage.

Analyses

Descriptive analyses for patient characteristics, process of care, and patient outcomes were performed. The percentage of patients with a time to intervention of <2 weeks, was calculated per hospital and compared with the national mean in a funnel plot. The national mean was derived from this dataset.

Possible associations between patient characteristics and outcomes, as mortality and (major) stroke/death were evaluated with a multivariable logistic regression model at a *p* value of 0.05 using an ENTER model. This analysis was used to adjust hospital outcomes for the casemix of their patients. Patient characteristics included in this analysis were based on the V(p)-POSSUM predictive score: sex, age, pulmonary status, cardiac status, pre-operative electrocardiogram, pre-operative creatinine level, and presenting symptoms.[9] A funnel plot with a confidence interval (CI) of 95% around the national mean was used to show hospital variation for casemix adjusted outcomes. Hospitals with a significantly lower major stroke/death than the national mean were identified as "hospitals with better outcomes" and hospitals with a higher major stroke/death as "hospitals with worse outcomes." Hospital and practice related factors were compared between hospitals with better outcomes and the other hospitals using chi-square tests. Finally, to identify risk factors for post-operative major stroke/death, a prediction model was formed, using a multivariable logistic regression model at a *p* value of 0.10 with backward elimination.

For missing data in continuous variables, the mean of each variable was imputed. Missing data in continuous variables did not exceed 5% of the total of each variable.

RESULTS

Patient characteristics

From January 2014 to December 2016, 6861 patients with a carotid artery stenosis undergoing carotid intervention were registered by 52 hospitals in The Netherlands. After exclusion of asymptomatic patients (274, 4.0%), all patients treated by CAS (122, 1.9%), and patients operated on in a hospital that stopped performing CEAs during the study period (6, 0.9%), 6459 patients were eligible for analysis and were included in this study. The cohort was predominantly male (4479, 69%) and had a mean age of 72.1 years. Patient characteristics are shown in Table 1.

Clinical presentation and process of care

The majority of patients presented with cortical symptoms (5,158, 79%) (Table 1). In 75% (4832) of patients the time to intervention was <2 weeks after the first hospital consultation. Fig. 1A shows the hospital comparison of the percentage of patients undergoing CEA <2 weeks after the first consultation. The median time to intervention varied between hospitals from 7 to 16 days.

A CEA with patch angioplasty was performed in the majority of patients (4,958, 77%), followed by eversion CEA (808, 12%) or CEA without patch angioplasty (693, 11%) (Table 2). General anaesthesia was used in 94% of patients, in 93% of whom intra-operative neurological monitoring was used. Intra-operative shunting was used in 20% of patients undergoing CEA, of which 69% were carried out

Table 1. Patient and disease characteristics.

	2014–2016	
Number of patients	6459	
Age	72.1 ± 9.3	
Sex		
Male	4479	69%
Female	1980	31%
Comorbidity		
Malignancy		
None	5485	85%
Current malignancy	152	2.4%
History of malignancy, curatively treated	822	13%
Pulmonary status		
No dyspnoea	5117	79%
Dyspnoea during exercise	1079	17%
Disabling dyspnoea	161	2.5%
Dyspnoea at rest/fibrosis	34	0.5%
Unknown	68	1.1%
Cardiac status		
None	2155	33%
Medication for hypertension	3624	56%
Peripheral edema	589	9.1%
Raised CVP	71	1.1%
Unknown	20	0.3%
Pre-operative ECG		
No abnormalities	3616	56%
Atrial fibrillation	428	6.60%
Ischaemia	127	2.0%
Other abnormalities	2062	32%
No pre-operative ECG performed	226	3.5%
Pre-operative laboratory results		
Haemoglobin	8.6 ± 1.04	
Sodium	139 ± 3.00	
Potassium	4.2 ± 0.42	
Creatinine	86 IQR 31	
Pre-operative systolic blood pressure	148 ± 23.0	
Pre-operative heart rate	74 ± 13.7	
Side of carotid artery stenosis		
Left	3318	51%
Right	3103	48%
Unknown	38	0.6%
Presenting symptoms		
Ocular symptoms	1192	19%
Cortical symptoms	5158	79%
Vertebrobasilar and other	109	1.7%
Previous CEA		
None	6162	95%
Yes, ipsilateral	66	1.0%
Yes, contralateral	218	3.4%
Yes, both sides	13	0.2%

CEA = carotid endarterectomy; CVP = central venous pressure; ECG = electrocardiogram.

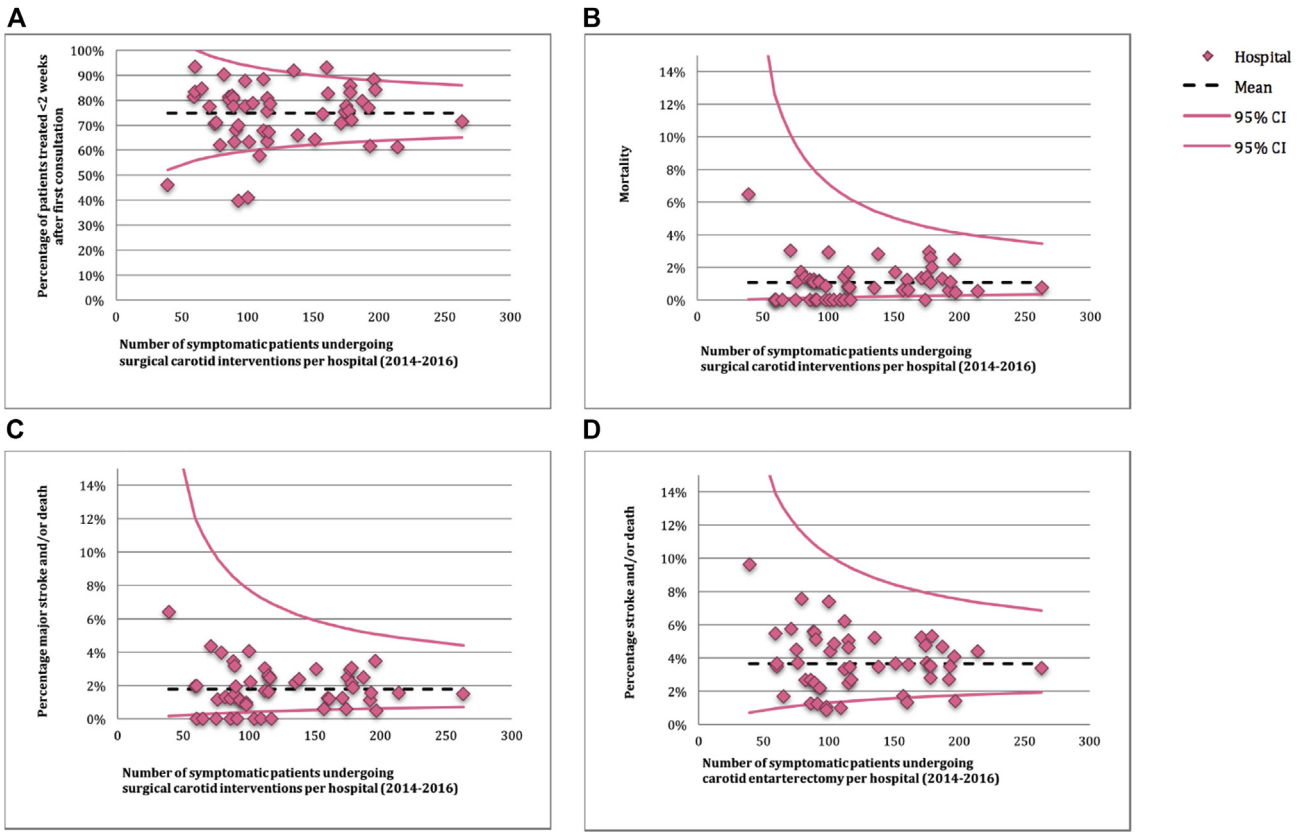

Figure 1. (A) Hospital comparison of time to intervention. (B) Hospital comparison of mortality. (C) Hospital comparison of major stroke and/or death. (d) Hospital comparison of stroke and/or death.

with intra-operative neurologic monitoring and 31% without. A small minority of 16 patients (0.2%) received no intra-operative neurological monitoring and no shunt, while being operated on under general anaesthesia.

Clinical outcomes

The 30 day/in hospital post-operative mortality was 1.1% (69) (Table 3). Mortality rates differed slightly between surgical procedures, but differences were not significant: CEA with patch angioplasty 0.4%, CEA without patch angioplasty 1.6%, or eversion CEA 0.9% ($p = .371$). Of all patients, 3.2% (206) had a post-operative stroke, of whom 62% (127) had a minor stroke and 38% (79) a major stroke. The combined major stroke/death and any stroke/death rate were 1.8% (115) and 3.6% (235), respectively. CNI and post-operative wound haemorrhage were observed in 2.8% (183) and 4.1% (262) of patients, respectively. A re-intervention was performed in 4.7% (305), of which the majority (86%) was for a post-operative wound haemorrhage and in 14% the indication was unknown.

Hospital comparison of outcomes

The multivariable logistic regression analyses for mortality, major stroke/death, and stroke/death are shown in Table 4. Pulmonary state (severe dyspnoea) and presenting with cortical symptoms were found to be significantly associated with all three outcome measures. Increasing age and female gender were associated with mortality and major stroke/death. Abnormalities on the last pre-operative electrocardiogram were associated with stroke/death.

Fig. 1B—D shows the casemix adjusted outcomes for respectively mortality, major stroke/death and any stroke/death by hospital volume for individual hospitals. The casemix adjusted mortality, major stroke/death, and any stroke/death rates varied, respectively, from 0 to 6.5%, 0 to 6.4%, and 0 to 9.6% between hospitals. Five hospitals had a significantly lower adjusted percentage stroke/death, when compared with the national mean. Additionally, nine hospitals had a significantly lower adjusted percentage major stroke/death. No hospital performed significantly worse than the mean.

As shown in Table 5, the patients operated on in the nine hospitals with better outcomes were more frequently referred from other hospitals, compared with patients operated in hospitals with a major stroke/death within the CIs. In contrast, these nine hospitals were more often hospitals with relatively lower volumes. The time to intervention did not differ between the two groups. General anaesthesia and CEA without patch angioplasty were more frequently used in these nine hospitals compared with the other hospitals. Additionally, peri-operative shunting was less often performed in these nine hospitals.

Patient, practice, and hospital related factors predictive of major stroke/death

Sex, age, pulmonary state, neurological presenting symptoms, and peri-operative shunting were predictive of major stroke/death, with an area under the curve of 0.691

Table 2. Treatment characteristics.

	2014–2016	
Number of patients	6459	
Imaging[a]		
Duplex	6311	98%
CTA	4237	66%
MRA	1313	20%
DSA	35	0.5%
Referral		
Internally	5267	82%
Tertiary	1188	18%
Unknown	4	0.1%
Time to carotid intervention[b]		
<2 weeks	4832	75%
>2 weeks	1582	25%
Unknown	45	0.7%
Surgical procedure		
CEA without patch angioplasty	693	11%
CEA with patch angioplasty	4958	77%
Eversion CEA	808	12%
Anaesthesia		
Local anaesthesia	368	5.7%
General anaesthesia	6084	94%
Unknown	7	0.1%
Neurological monitoring		
No monitoring	435	6.7%
Awake patient	314	4.9%
EEG	2822	44%
Stump pressure	130	2.0%
EEG and TCD	2693	42%
Other combinations	65	1.0%
Shunting during surgery		
No shunting	4629	72%
Shunting	1262	20%
Unknown	568	8.8%
Post-operative medication		
Acetylsalicylic acid	2441	38%
Statin	5519	85%
Dipyridamole	851	13%
Coumarin	364	5.6%
Clopidogrel	4247	66%
Antihypertensive medication	4348	67%
New anticoagulants	90	1.4%
Heparin[c]	5378	83%

CEA = carotid endarterectomy; CTA = computed tomography angiography; DSA = digital subtraction angiography; EEG = electroencephalogram; MRA = magnetic resonance angiography; TCD = transcranial doppler; CVP = central venous pressure.

[a] In 79.9% a combination of diagnostic imaging was used.

[b] Time from first consultation at the hospital to CEA.

[c] Post-operative use of heparin as venous thromboembolism prophylaxis is protocolled in The Netherlands.

(Table 6). All patient, treatment, and hospital related factors used in this analysis that were proven not to be predictive for major stroke/death are shown at the bottom of Table 6.

DISCUSSION

The DACI has been successfully implemented in the Netherlands and covers all Dutch centres, which allows evaluation of quality of care in CEA both nationally and between hospitals. In The Netherlands, CEA is performed with an overall low mortality and (major) stroke/death rate and a reasonable guideline adherence, considering time to intervention. Whereas time to intervention showed significant variation between hospitals, outcome indicators such as mortality and (major) stroke/death are not very distinctive because of low overall event rates and no hospitals with a significantly higher event rate. The lack of hospitals with worse outcomes in these indicators hampers a national hospital comparison in the era with a minimum volume of 20 CEA per year per hospital. However, nine hospitals with a significantly lower major stroke/death rate than the national mean were identified, from which others could perhaps learn. Additionally, predictors of major stroke/death after CEA in symptomatic patients could be identified with the use of DACI data.

Clinical audits are increasingly appreciated as a tool for quality improvement in surgical care and have proven to be effective.[10] A clinical audit provides insight into the process of care and patient outcomes and enables comparison with other healthcare providers, so that areas for improvement can be identified and targeted improvements can be started. Moreover, with a nationwide audit, volume standards and national guideline adherence can be monitored.

For carotid artery interventions, several national audits have been successfully initiated in recent years.[11–13] Additionally, some countries are collaborating in VASCUNET, a subcommittee of the European Society of Vascular Surgery, which makes it possible to compare practice between countries.[5] The percentage of asymptomatic patients undergoing CEA in other European countries varies from <1% to 53%.[5,11] In the DACI 93% of patients had a symptomatic stenosis and 75% of these patients were treated <2 weeks after their first consultation in the hospital, with a variation of 40–93% between hospitals. The national guideline aims to treat at least 80% of symptomatic patients <2 weeks after the first consultation, consequently this leaves room for improvement. A score of 100% may not be realistic, as patient delay can always occur. Besides the Scandinavian countries, in which 82.5% of patients are treated <2 weeks, most countries have logistic obstacles to treating symptomatic patients within this timeframe.[11,14] As it is known that the risk of a recurrent stroke is greatest in the first days after the index event, ideally symptomatic patients should be treated even sooner.[15] Therefore, time to intervention will remain a topic of attention and possibly the permitted timeframe will be shortened in the future. The stroke/death rate in the DACI is comparable with outcomes in other audits, with stroke/death rates varying between 0.9% and 4.6%.[5,12,14,16–18] It should be noted that national audits often use the outcome measure any stroke/death, while the landmark trials also used major stroke/death.[19,20] The present authors believe that it is important to make a distinction in the severity of a post-operative stroke and that major stroke/death is a more uniform measure.

CNI and post-operative wound haemorrhage, measured at 30 day/in hospital, were, respectively, 2.8% and 4.1%. The

Table 3. Outcomes 30 days post-operatively and/or during admission.

	2014–2016	
Number of patients	6459	
Post-operative period		
Stroke	206	3.2%
Cranial nerve injury	183	2.8%
Haemorrhage	262	4.1%
Complications		
Other surgical complication	109	1.7%
General complication	384	5.9%
Other	108	1.7%
Re-intervention	305	4.7%
Death	69	1.1%
Major stroke and/or mortality	115	1.8%
Stroke and/or mortality	235	3.6%

reported frequencies of CNI vary widely in other studies, as the study design, method of diagnosing the injury, and whether or not the patient was assessed by a neurologist also varies per study. This last point is also applicable to the DACI, which entails the risk of underreporting of stroke and/or CNI. However, it has been shown that the majority of CNI will resolve over the first few months and permanent CNI is rare.[21,22]

Additionally, this study shows a hospital comparison of outcomes after CEA in symptomatic patients. With the national minimum threshold of 20 CEA per hospital per year, the majority of hospitals have outcomes comparable with the national mean and there are no hospitals performing worse. To improve quality of care, one should look for "best practice hospitals" or variation between hospitals. An outcome measure like mortality, with a low event rate, shows little variation between hospitals. Some hospitals had no mortality, but this was often not significantly better than the mean. With the outcome measure any stroke/death and major stroke/death, more variation was observed and, respectively, five and nine hospitals with a significantly lower (major) stroke/death rate could be observed. However, most hospitals perform within the CIs. When comparing those nine hospitals with a significantly lower major stroke/death rate than the national mean with the other hospitals, some differences in practice were seen. Those nine hospitals mostly had lower volumes; however, this is relative and therefore the minimum volume of 20 seems to be sufficient. Patients were more often referred, general anaesthesia was more often used, and in almost all patients intra-operative neurological monitoring was used. Furthermore, peri-operative shunting was less often used in these nine hospitals, which appeared to be predictive of major stroke/death. Noteworthy, is that previous studies showed contradictory results about the association between peri-operative shunting and (major) stroke/death.[23,24] Further research is needed to confirm this association. Patient and disease related factors such as female sex, increasing age, severe dyspnoea, and cortical symptoms as presenting symptoms were predictive of major stroke/death in symptomatic patients, which was partly confirmed in a previous study,[25] whereas another study showed that cardiac disease was also predictive of (major) stroke/death. Additionally, smoking, diabetes, and the urgency of the surgery were proven to be predictive of (major) stroke/death, but these variables were not included in the present model.[17,26,27]

Table 4. Patient characteristics predictive for mortality, stroke/mortality, and major stroke/mortality.

	Mortality		Major stroke/mortality		Stroke/mortality	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Number of patients	6459		6459		6459	
Age	1.05	1.015–1.077	1.035	1.012–1.058	1.014	0.999–1.030
Sex						
Male	Ref		Ref		Ref	
Female	1.970	1.217–3.187	1.585	1.074–2.337	1.218	0.917–1.616
Pulmonary state						
No dyspnoea	Ref		Ref		Ref	
Dyspnoea	0.529	0.238–1.178	0.803	0.472–1.368	1.047	0.740–1.481
Severe dyspnoea	3.978	1.907–8.298	3.013	1.567–5.795	2.323	1.373–3.930
Cardiac state						
No abnormalities	Ref		Ref		Ref	
Cardiac comorbidities	1.188	0.675–2.090	1.265	0.809–1.893	1.280	0.933–1.757
Last pre-operative ECG						
No abnormalities	Ref		Ref		Ref	
Abnormalities (atrial fibrillation, ischaemia and others)	1.402	0.848–2.317	1.282	0.868–1.893	1.470	1.116–1.936
Presenting symptoms						
Ocular symptoms	Ref		Ref		Ref	
Cortical symptoms	3.065	1.109–8.472	2.345	1.179–4.664	2.345	1.179–4.664
Vertebrobasilar or other symptoms	2.320	0.255–21.086	2.175	0.462–10.252	2.175	0.462–10.252
Pre-operative laboratory results						
Creatinine [a]			1.001	0.996–1.005	1.001	0.996–1.005

[a] Pre-operative creatinine level not included in the multivariable logistic regression analysis for mortality because of the limited degrees of freedom.

Table 5. Comparison of hospital related factors between hospitals with a lower percentage major stroke/death and hospitals performing within the CIs.

	Not treated in "best practices" N = 5555	%	Treated in "best practices" N = 904	%	p
Referral					
Internal	4633	83%	634	70%	0.000
Tertiary	920	17%	268	30%	
Hospital volume (3 years)					0.000
Low volume (0–110)	1668	30%	590	65%	
Normal volume (111–175)	2107	38%	117	13%	
High volume (176–263)	1780	32%	197	22%	
Time to intervention					
> 2 weeks	1383	25%	199	22%	0.170
< 2 weeks	4134	74%	698	77%	
Unknown	38	0.7%	7	0.8%	
Anaesthesia					0.000
Local	363	6.5%	6	0.7%	
General	5193	94%	898	99%	
Surgical procedure					0.000
CEA without patch	554	10%	139	15%	
CEA with patch	4303	78%	655	73%	
Eversion CEA	698	13%	110	12%	
Peri-operative shunting					0.000
No shunting	3901	70%	728	81%	
Shunting	1159	21%	103	11%	
Unknown	495	8.9%	73	8.1%	
Neuro-monitoring					0.000
No monitoring	428	7.7%	7	0.8%	
EEG	2283	41%	539	60%	
Stump pressure	130	2.3%	0	0.0%	
Awake patient	314	5.7%	0	0.0%	
EEG/TCD	2342	42.2%	351	38.8%	
Other (combinations of) monitoring	58	1.0%	7	0.8%	

CEA = carotid endarterectomy; EEG = electrocardiogram; TCD transcranial doppler.

Table 6. Factors predictive of major stroke/death.

	Odds ratio	95% CIs
Age	1.038	1.016–1.061
Sex		
Male	Ref	
Female	1.486	1.017–2.170
Pulmonary state		
No dyspnoea	Ref	
Dyspnoea	0.821	0.484–1.392
Severe dyspnoea	3.300	1.718–6.340
Presenting symptoms		
Ocular symptoms	Ref	
Cortical symptoms	2.130	1.068–4.246
Vertebrobasilar or other symptoms	2.113	0.448–9.966
Peri-operative shunting		
No shunting	Ref	
Shunting	2.484	1.664–3.707
Unknown	1.708	0.910–3.207

Eliminated variables: heart rate, potassium, hospital volume, haemoglobin, creatinine, anaesthesia, systolic blood pressure, sodium, surgical procedure, cardiac state, time to intervention, neurological monitoring, pre-operative ECG.

Although some differences in outcomes were observed, no hospitals were identified with significantly worse practice. This may be caused by the low event rate. In the future, other ways to identify the possible existing variation in quality of care of CEA between hospitals need to be explored. A possible solution, that was recently tested for aortic aneurysm surgery, could be the development of a composite measure, Textbook outcome, combining process and outcome measures by which a more complete picture of care can be provided.[28]

In its current form, the DACI has several limitations. As the DACI is an audit of carotid interventions, it does not contain information on patients who did NOT receive surgical treatment. Therefore, the audit does not provide information on intervention rate and neurological outcome of all patients with a symptomatic stenosis. With a future link between data from the DACI and data from the Dutch Acute Stroke Audit, this will be possible. With this link, the timeframe between first event and intervention can also be provided, which is more important from a patient perspective. Secondly, the severity of the presenting stroke was not captured in all symptomatic patients, which is important if you want to compare hospitals as fairly as possible on patient outcomes. This will be altered in the next update of the web survey. The data are self reported so it is possible that the reported mortality and complications are slightly underestimated. A continuously repeated independent data verification will be carried out to minimise this possible discrepancy. Additionally, standardising post-

operative care and follow up could improve quality of care and could contribute to data quality. Lastly, the DACI only provides information on 30 day/in hospital outcomes, while the long-term complications and re-interventions are just as important. A future possible link with declaration data from healthcare insurers might be able to provide this information.

Next to the comparison of results between hospitals on a national level, one could also learn from the comparison of practice and outcomes between different countries. Describing the initiation and first results of the present nationwide audit for carotid interventions could be helpful for other countries and may be an incentive for them to establish a similar audit or encourage harmonisation of existing national audits. A future international collaboration, in which practice and outcomes can be compared and in which one could learn from each other, could contribute to further quality improvements on a wider scale.

CONCLUSION

In The Netherlands CEA is performed with an overall low mortality and (major) stroke/death rate and a reasonable time to intervention. Whereas time to intervention showed significant variation between hospitals, outcome indicators such as mortality and (major) stroke/death are not very distinctive because of low overall event rates and no hospitals with a significantly higher event rate. Hospital comparison and the identification of "best practices" is hampered by this lack of variation between hospitals in current outcome indicators. However, data from the DACI can be used for national population studies, such as identification of predictors of major stroke/death in symptomatic patients.

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CONFLICTS OF INTEREST

No conflicts of interest.

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APPENDIX 1. LIST OF ITEMS REGISTERED IN THE DACI

Number	Label
	Section
1	Sex
2	Year of birth
	Section
3	History of malignancies
4	Pre-operative cardiac state
5	Pre-operative pulmonary state
6	Pre-operative systolic blood pressure
7	Pre-operative heart rate
8	Pre-operative haemoglobin
9	Pre-operative leukocytes
10	Pre-operative sodium
11	Pre-operative potassium
12	Pre-operative creatinine
13	Pre-operative results of ECG
	Section
14	Side of intervention
15	Indication for intervention
16	Namely,
17	Date of first symptoms
18	Specialty of first consultation at the hospital
19	Date of first consultation at the hospital
20	Way of referral
21	Date of first surgical consultation/date of multidisciplinary consultation
22	Previous CEA
	Section Pre-operative investigations
23	DUPLEX
24	CTA
25	MRA
26	DSA
	Section Pre-operative medication
27	Acetylsalicylic acid
28	Statin
29	Dipyridamole
30	Coumarin
31	Clopidogrel (Plavix)
32	Antihypertensive agents
33	NOAC
34	Heparin
	Section
35	Intervention
36	Date of intervention
37	Reason for intervention
38	Glasgow Coma Scale, eyes
39	Glasgow Coma Scale, movements
40	Glasgow Coma Scale, verbal
41	Anaesthesia
42	Monitoring

-continued

Number	Label
43	Awake during intervention
44	EEG
45	TCD
46	Stump pressure
47	Type of procedure
48	Use of shunt
49	Blood loss
	Section Post-operative medication
50	Acetylsalicylic acid
51	Statin
52	Dipyridamole
53	Coumarin
54	Clopidogrel (Plavix)
55	Antihypertensive agents
56	NOAC
57	Heparin
58	Other medication
59	Namely,
	Section
60	Post-operative TIA/stroke
61	New or worsening neurological deficit
62	Specify TIA/stroke
63	Ipsilateral TIA/stroke
64	Contralateral TIA/stroke
65	Pre-operative neurological state
66	Post-operative neurological state (30 days)
67	Discharge to home/nursing home
68	Cranial nerve injury
69	Wound haemorrhage
70	Other complications
71	Namely,
72	Re-intervention
73	Indication for re-intervention
74	Other
75	Number of days on ICU
76	Mortality (30 day/in hospital)
77	Mortality (30 day/in hospital)

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