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Factors Associated with Hospital Dependent Delay to Carotid Endarterectomy in the Dutch Audit for Carotid Interventions

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WHAT THIS PAPER ADDS

This paper identifies factors that are associated with hospital dependent delay to carotid endarterectomy (CEA) using data from a nationwide mandatory clinical audit in the Netherlands. By establishing these factors, other hospitals can learn which patients are at risk of a longer waiting time for CEA and can evaluate their own protocol accordingly.

Objectives: As the risk of a recurrent neurological event in patients with symptomatic carotid stenosis requiring carotid endarterectomy (CEA) is highest in the early phase after the first neurological event, guidelines recommend operating on these patients as soon as possible or at least within 14 days of their initial event. However, in real world practice this is often not met. The aim of this study is to identify factors that cause hospital dependent delay to CEA.

Methods: All consecutive patients with symptomatic carotid stenosis undergoing CEA registered in the mandatory Dutch Audit for Carotid Interventions from January 2014 up to and including December 2017 were included in the current analysis. Univariable followed by multivariable logistic regression was used to identify independent factors associated with hospital dependent waiting time, defined as time from the first consultation at any hospital to CEA of more than 14 days.

Results: A total of 8620 patients were included. The median time to CEA was 11 days (IQR 8—14). Seventy-eight per cent of patients underwent CEA within 14 days of first hospital consultation. Factors associated with a hospital dependent waiting time longer than 14 days were age (OR 0.99 per year, 95% CI 0.98—0.99), any previous CEA (OR 1.67, 95% CI 1.32—2.09), ocular symptoms as index event (OR 1.31, 95% CI 1.15—1.50), and indirect referral (OR 1.53, 95% CI 1.34—1.73). Hospital surgical volume was not identified as a factor for delay, except for the delay of indirectly referred patients where high volume hospitals reported the shortest delay.

Conclusion: This cohort derived from a validated nationwide prospective audit identified younger age, previous CEA, ocular symptoms, and indirect referral as hospital dependent factors for delay. High volume hospitals had a similar hospital dependent waiting time to middle and low volume hospitals. However, high volume hospitals had more indirect referrals, implying that their logistics are more efficiently organised.

Keywords: Audit, Carotid endarterectomy, Delay, Quality of care
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INTRODUCTION

In patients with a high degree symptomatic carotid artery stenosis, recurrent ischaemic events can be adequately prevented by carotid revascularisation.[1] Although carotid artery stenting (CAS) has been suggested as an equally effective therapeutic option in the prevention of stroke, all randomised trials comparing carotid endarterectomy (CEA) with CAS have revealed a significantly higher minor stroke rate with CAS.[2] Based on these findings, in the Netherlands CEA is performed predominantly in symptomatic patients. In recent years, the relevance of timely CEA after a presenting stroke has become evident. The risk of a recurrent

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event is highest shortly after the presenting event: from 5.2% within two days, up to 11.2% within 14 days, and 18.6% within 90 days.[3] As a result of this initially high recurrence risk, international guidelines recommend performing carotid revascularisation within 14 days of the first event.[4] In practice, this guideline is often not met,[5] although earlier CEA reduces the recurrent ischaemic event rate.[6] Therefore in recent years, multiple studies have investigated factors associated with this delay. These factors can be divided into two categories: pre-hospital dependent delay and hospital dependent delay. Pre-hospital dependent delay can, for instance, be caused by the patient not identifying functional deficits as neurological events. Hospital dependent delay, defined as the time from first consultation at any hospital until carotid revascularisation, is subject to the organisation of care within and between hospital(s). This latter form of delay can be used as an indicator of the quality of care provided by each hospital. In the Netherlands, all patients undergoing carotid interventions are registered in the Dutch Audit for Carotid Interventions (DACI), a nationwide mandatory audit. The percentage of symptomatic patients operated on within 14 days of first consultation at any hospital has been made public each year since the start of the audit in 2013, thereby encouraging data driven improvement. By identifying factors causing hospital dependent delay, targeted action can be made to reduce hospital dependent waiting time. With earlier intervention, theoretically potential recurrent events might be prevented.

The aim of this study was to identify patient and hospital factors that lead to a hospital dependent waiting time above 14 days.

MATERIALS AND METHODS

Data source

The DACI is a mandatory, nationwide, population based prospective audit in which data of all consecutive patients undergoing carotid revascularisation have been registered prospectively since 2013. A recent evaluation of the validity of the data performed in hospitals selected at random showed 99.3% completeness. The DACI is managed by the Dutch Society for Vascular Surgery, a professional association for vascular surgeons. The audit uses indicators to measure the quality of care and provide a national benchmark.[7] The percentage of symptomatic patients treated within 14 days of their first consultation at any hospital is a quality indicator set by the Dutch Society for Vascular Surgery and enforced by the Health and Youth Care Inspectorate.

Patient selection

For this study, all consecutive patients in the Netherlands undergoing CEA for symptomatic carotid stenosis from January 2014 up to and including December 2017 were included. Symptomatic carotid stenosis was defined by the occurrence of ocular or cerebral transient ischaemic attack (TIA) and/or ischaemic stroke in patients with high degree stenosis. In the Dutch current treatment guidelines, high degree symptomatic stenosis is defined as a stenosis of 70—99% of the ipsilateral internal carotid artery, with the exception of male patients with a stenosis of 50—99% with cerebral (and not ocular) symptoms, measured using the method of the North American Symptomatic Carotid Endarterectomy Trial (NASCET).[8] Asymptomatic patients were excluded from this analysis, as these patients lack an index primary event and therefore are not at risk of a recurrent event. Also excluded were patients treated by carotid artery stenting because of the small number of patients and different treatment modality. Minimum data requirements for inclusion were age, date of carotid intervention, type of carotid intervention, and 30 day survival status. The data were collected with a waiver of patient consent, as is common in clinical audits.

Definitions

Date of CEA was used to determine the year of inclusion. Cardiac morbidity was defined as the presence of hypertension, angina, cardiomegaly, cardiomyopathy, or abnormalities on electrocardiogram. The patient had respiratory morbidity if they had any signs of dyspnoea from pulmonary disease or visible consolidation or signs of fibrosis on chest X-ray. Ocular symptoms could be either amaurosis fugax or a retinal artery occlusion. A patient was indirectly referred when they presented with (a history of) TIA or ischaemic stroke in a hospital other than where the CEA was performed. Directly referred patients presented at the hospital where the CEA was performed. Hospital dependent waiting time, that is waiting time to CEA, was defined as the date of first consultation at any hospital to the date of carotid intervention in days, corresponding with the national quality indicator. Time to first outpatient visit/vascular meeting was defined as time from first consultation at any hospital to the first outpatient visit with the vascular surgeon prior to the operation or to a multidisciplinary vascular meeting in which the indication for surgery for each patient was discussed. Date of first/index event and type of first/index event were not registered in the DACI until 2018.

Analysis

Continuous values were expressed as mean with standard deviation (SD) and nominal variables as count and percentages. Time intervals were not normally distributed values and therefore summarised by median and corresponding interquartile ranges (IQR). The chi-square test was used to compare categorical data for each year. The Mann—Whitney *U* test and Kruskal—Wallis test were used for age and time intervals, respectively.

A logistic regression analysis was performed to identify patient factors and hospital factors associated with hospital dependent waiting time, defined as waiting time from first consultation at any hospital to CEA above 14 days.

Covariates used for analysis were age (in years, continuous), sex, respiratory morbidity, cardiac morbidity, use of oral anticoagulants, any previous CEA, first consultation at hospital during the weekend, presenting symptoms (cerebral/ocular), and referral. There was collinearity between ocular symptoms and referral by an ophthalmologist, and therefore referral by ophthalmologist was left out of the logistic regression analysis. In addition to univariable analysis, factors with a p value of $< .1$ were selected for multivariable analysis. Factors were added using forward selection. The discrimination of the regression model was tested using a receiver operator curve (ROC) to estimate the area under the ROC curve (AUC). The goodness of fit of the model was tested using a Hosmer—Lemeshow test.

Subsequently, the association between volume and hospital dependent delay was investigated. Hospitals were categorised by volume into tertiles: hospitals with an average of less than 37 CEAs a year were classified as low volume, an average between 37 and 55 as medium volume, and 55 or higher as high volume. The chi-square test was used to compare the hospital dependent waiting time in the different volume categories.

All statistical analyses were performed with R software (version 1.1.383).

RESULTS

In total, 9293 patients were registered in the DACI. After excluding the patients undergoing CAS (353 patients) and the asymptomatic patients (320 patients), 8620 patients were included in the present analysis.

Baseline characteristics over time

An overview of the baseline characteristics, in total and divided per year, are shown in Table 1.

The mean age of the patients was 72 years and age increased statistically significantly over the years (although not clinically relevant). Seventy per cent of the patients were male. The number of hospitals performing CEA decreased from 54 in 2014 to 52 in 2017 ($p < .001$). All hospitals performed according to the minimum surgical volume standard of 20 interventions a year. Most patients (75%) had cardiac comorbidities, which increased during the years of registration ($p < .001$). Twenty per cent had respiratory morbidity. Four per cent of the patients had

Table 1. Baseline characteristics of patients studied for hospital dependent delay for carotid endarterectomy (CEA) for symptomatic carotid stenosis in total and divided by year of inclusion.

Characteristics	Year of inclusion					p[a]
	Total $n = 8620$	2014 $n = 2010$	2015 $n = 2188$	2016 $n = 2231$	2017 $n = 2191$	
Hospitals − n	54	54	54	54	52	<.001
Patient characteristics						
Age − y	72 ±9	72 ±9	72 ±9	72 ±9	73 ±9	.01
Male sex	6010 (70)	1396 (69)	1512 (69)	1558 (70)	1554 (70)	.76
Comorbidity						
Respiratory morbidity	1710 (20)	367 (18)	468 (21)	433 (19)	442 (21)	.08
Cardiac morbidity	6437 (75)	1419 (72)	1640 (75)	1690 (76)	1688 (77)	<.001
Use of oral anticoagulants	1027 (12)	203 (10)	269 (12)	284 (13)	271 (12)	.04
Previous CEA	375 (4)	83 (4)	105 (5)	106 (5)	81 (4)	.22
Indication for intervention						
Cerebral symptoms	7001 (81)	1603 (80)	1775 (81)	1845 (83)	1778 (81)	.11
Ocular symptoms	1619 (19)	407 (20)	413 (19)	386 (17)	413 (19)	
Process factors						
First consultation at hospital during the weekend	1232 (14)	300 (14)	347 (16)	313 (14)	272 (14)	.22
Referring specialist						
Neurologist	7887 (93)	1812 (91)	1986 (93)	2093 (95)	1996 (92)	<.001
Ophthalmologist	395 (5)	97 (5)	100 (5)	81 (4)	117 (6)	
Vascular surgeon	208 (2)	74 (4)	48 (2)	36 (2)	50 (2)	
Indirectly referred	1564 (18)	328 (16)	404 (18)	435 (19)	397 (18)	.06
Time to CEA						
Median hospital dependent waiting time to first outpatient visit/vascular meeting − d (IQR)	3 (1−6)	4 (1−7)	3 (1−6)	3 (1−6)	3 (1−6)	<.001
Median hospital dependent waiting time to CEA − d (IQR)	11 (8−14)	12 (8−15)	11 (8−14)	11 (8−14)	10 (7−13)	<.001
Patients with time to CEA within 14 days	6645 (78)	1397 (70)	1651 (76)	1755 (79)	1842 (85)	<.001

Data are given as n (%) or mean ± stand deviation (SD) unless stated otherwise.
CEA = carotid endarterectomy; IQR = interquartile range.
[a] p value of difference between years of inclusion.

previously undergone a CEA (either ipsilateral or contralateral).

In most patients, cerebral symptoms were a manifestation of the carotid stenosis (81%). Most patients were referred by a neurologist (93%). Eighteen per cent were indirectly referred. The median time to first outpatient visit/vascular meeting decreased from four days in 2014 to three days in the following years, which was statistically significant but not clinically relevant. Median hospital dependent waiting time to CEA decreased from 12 days (IQR 8–15) in 2013 to 10 days (IQR 7–13) in 2017. Subsequently, more patients were treated within 14 days or less in 2017 compared with 2014 (85% *vs.* 70%, $p \leq .001$).

Factors associated with a hospital dependent waiting time above 14 days

Factors associated with a hospital dependent delay are shown in Table 2. These factors were age (OR 0.99 per year, 95% CI 0.98–0.99), any previous CEA (OR 1.67, 95% CI 1.32–2.09), ocular symptoms as index event (OR 1.31, 95% CI 1.15–1.50), indirect referral (OR 1.53, 95% CI 1.34–1.73), and year of inclusion (OR 2.35 [95% CI 2.02–2.74] in 2014, OR 1.72 [95% CI 1.72–2.01] in 2015 and OR 1.44 [95% CI 1.23–168] in 2016, with 2017 as reference). Referral by a neurologist, independent of type of symptoms, was associated with a shorter waiting time (OR 0.70, 95% CI 0.59–0.84). The area under the ROC curve of the model was 0.62 ($p < .001$). The Hosmer–Lemeshow test showed a p value of .99, indicating that there is no evidence that this model fits badly.

Twenty-three per cent of ocular patients were referred by an ophthalmologist. Of these patients, 58% were operated on within 14 days (*vs.* 76% when referred by a neurologist).

Association between volume and waiting time to CEA

The median hospital dependent waiting time was 11 days for low, middle and high volume hospitals with a similar interquartile range (Fig. 1). Between the three different categories, no difference was found in percentage of patients undergoing CEA within 14 days ($p = .7$).

Association between referral and waiting time to CEA

A difference in hospital dependent waiting time was seen in patients who were indirectly referred compared with patients who were directly referred (Fig. 2). If patients were directly referred, 79% were treated by CEA within 14 days compared with 71% of the indirectly referred patients ($p < .001$). For both groups, the percentage of patients undergoing CEA increased for each year (Fig. 2). When comparing directly and indirectly referred patients for each year, the difference between the groups remained statistically significant (p value for each year: < .001 [2014], .01 [2015], <.001 [2016], and .03 [2017]).

In directly referred patients, there was no difference in the percentage of patients who were operated upon within 14 days between low, middle, and high volume hospitals (21% *vs.* 20% *vs.* 22%, $p = .27$). In low volume hospitals, the

Table 2. Factors associated with a hospital dependent waiting time longer than 14 days to carotid endarterectomy (CEA) for symptomatic carotid stenosis

Factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Age	0.99 (0.98–0.99)	<.001	0.99 (0.98–0.99)	<.001
Sex				
Male	0.97 (0.87–1.08)	.56	–	
Female	Reference			
Respiratory comorbidity	1.11 (0.97–1.25)	.12	—	
Cardiac comorbidity	0.98 (0.87–1.10)	.72	—	
Use of oral anticoagulants	1.07 (0.91–1.25)	.40	—	
Any previous CEA	1.74 (1.39–2.16)	<.001	1.67 (1.32–2.09)	<.001
Symptoms at index event				
Ocular symptoms	1.50 (1.32–1.69)	<.001	1.31 (1.15–1.50)	<.001
Cerebral symptoms	Reference			
First consultation during weekend	0.99 (0.85–1.14)	.87	–	
Neurologist as referring specialist	0.57 (0.48–0.67)	<.001	0.70 (0.59–0.84)	<.001
Vascular surgeon as referring specialist	1.06 (0.75–1.45)	.74	–	
Referral				
Directly referred	Reference			
Indirectly referred	1.55 (1.37–1.75)	<.001	1.53 (1.34–1.73)	<.001
Year of inclusion				
2014	2.34 (2.02–2.73)	<.001	2.35 (2.02–2.74)	<.001
2015	1.73 (1.49–2.02)	<.001	1.72 (1.48–2.01)	<.001
2016	1.43 (1.23–1.67)	<.001	1.44 (1.23–1.68)	<.001
2017	Reference			

CEA = carotid endarterectomy; CI = confidence interval; OR = odds ratio.

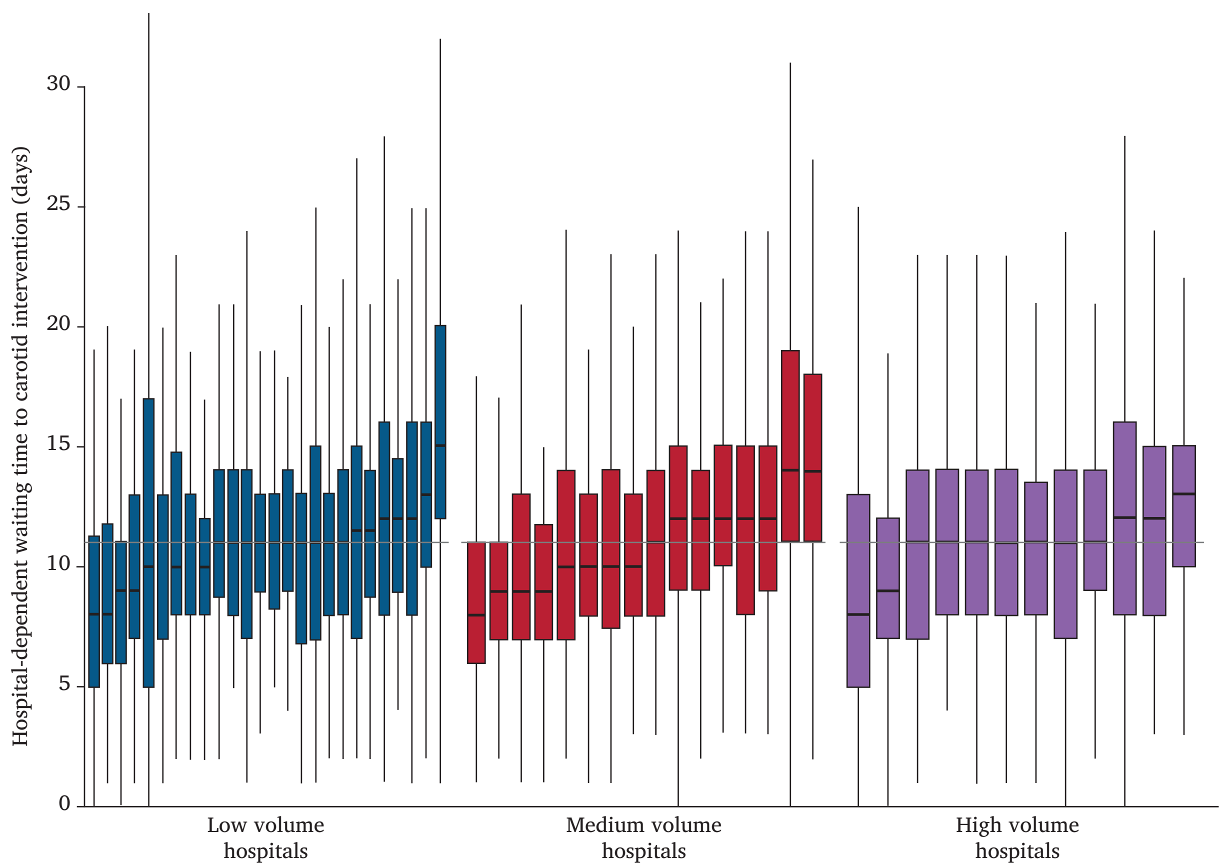

Figure 1. Boxplots of hospital dependent waiting time to carotid endarterectomy for symptomatic carotid stenosis for each hospital. The whiskers represent the 5th to 95th percentile. Hospitals were categorised on the basis of volume for each hospital. The median hospital dependent waiting time of 11 days is shown in grey.

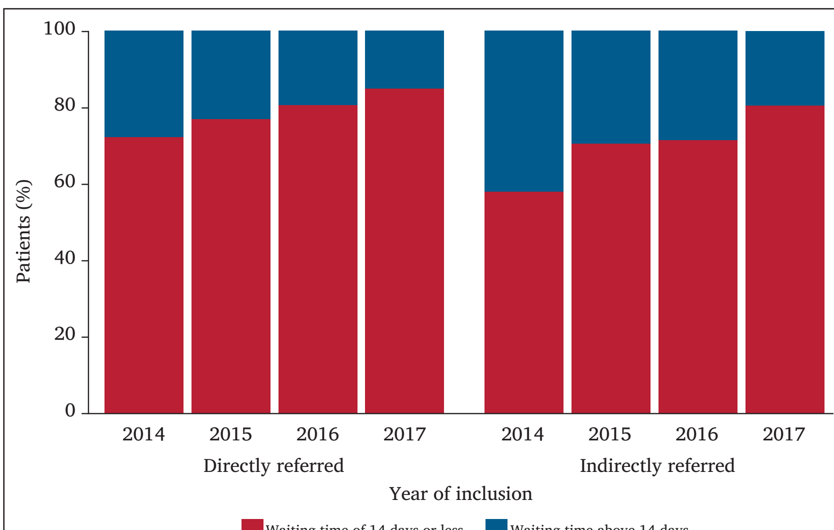

Figure 2. Percentage of patients undergoing carotid endarterectomy for symptomatic carotid stenosis within 14 days of first presentation at hospital for each year. Patients are divided into groups of patients directly and indirectly referred.

percentage of patients indirectly referred was lower than in middle and high volume hospitals (low: 11%, middle: 23%, and high: 21%, $p < .001$). In indirectly referred patients, 28% of patients were operated on after more than 14 days in low volume hospitals, 33% in middle volume hospitals, and 26% in high volume hospitals.

DISCUSSION

Using data from a nationwide audit, this study identified younger age, previous CEA, ocular symptoms as index event, and indirect referral as factors associated with a hospital dependent delay, defined as a waiting time above 14 days from first consultation at any hospital to CEA. The number of CEA procedures at the hospital was not associated with hospital dependent delay.

The guidelines of the European Society for Vascular Surgery recommend that patients should be operated on within 14 days of the onset of symptoms.[9] From a pathophysiological point of view, this is indeed the single most relevant timeframe. Therefore, this timeframe was used in previous studies investigating factors associated with delay to CEA. However, when investigating hospital performance in a nationwide audit, which is the primary aim of DACI, the time from first consultation at any hospital to carotid intervention is the most relevant timeframe. By identifying patients at high risk of hospital dependent delay, identified using data from a large nationwide mandatory clinical audit, hospitals can evaluate their protocol accordingly, and this could be used as a recommendation for reducing time to intervention for future updates of the abovementioned guidelines.

The factors associated with time from event to CEA, found in previous studies, were TIA as index event, ocular symptoms as index event, and indirect referral.[10–13] Ocular symptoms are often not identified as an ischaemic event by patients and/or general practitioners, therefore pre-hospital dependent delay is inevitable. However, in the present study these were identified as a factor for hospital dependent delay, implying that a retinal artery occlusion or amaurosis fugax are more difficult to diagnose than a cerebral TIA or infarction and therefore are not referred with high urgency. Because of collinearity with ocular symptoms, referral by an ophthalmologist was excluded from the logistic regression. When comparing the waiting time between ophthalmologist and neurologist, initial consultation with an ophthalmologist was associated with a higher percentage of a waiting time above 14 days. This may imply that more awareness among ophthalmologists is needed so that these patients are referred earlier. Another similar factor to previous studies is referral. Patients who are referred from a different hospital to a centre for CEA are associated with greater waiting time. Better referral protocols between hospitals must be made to speed up this process. Furthermore, the number of CEA procedures per hospital did not affect the waiting time, as also shown in a recently published study.[14] However, low volume hospitals treat relatively more directly referred patients than middle or high volume hospitals. When performing a subgroup analysis on indirectly referred patients, middle volume hospitals had a statistically significantly higher percentage of patients with a waiting time above 14 days than high volume hospitals, while treating a similar percentage of indirectly referred patients. This implies that high volume hospitals have better logistics within the hospital. Furthermore, a recent meta-analysis showed that high volume hospitals have a decreased risk of procedural death and stroke.[15] Therefore, fear of delay to CEA should not stand in the way of referring patients to high volume hospitals. To reduce delay, the present authors advise the multidisciplinary teams involved in treatment of symptomatic patients with high degree carotid stenosis considered an indication of revascularisation, to review their protocol regarding carotid revascularisation. As most patients are first examined by neurologists or ophthalmologists, multidisciplinary arrangements must be made to safeguard a quick referral.

The present study found that younger age and any previous CEA were additional factors when looking solely at hospital dependent delay. A possible explanation for delay in younger patients is that more extensive screening is performed for causes of young stroke, which is more time consuming. Another explanation could be that younger patients are more likely to have TIA than stroke, which could account for the longer delay. As for delay in patients with previous CEA, this could be explained by the procedure itself being more complex after a previous CEA and therefore could be postponed.

Overall, when testing for goodness of fit for the model, there was no evidence that the model fits badly. Although the discriminatory power of the model, expressed as the AUC of the ROC, was weak, this study has provided information on which patients are at high risk of a hospital dependent delay, although some additional factors not registered in the DACI should exit. It is believed that these unidentified factors involve logistics within and between hospital(s), which could play an important role in succeeding to perform operations within two weeks of presentation, but this is difficult to grasp in a nationwide clinical audit. An in depth survey will be carried out to further investigate this in the near future.

Several limitations can be identified. First, only patients who actually underwent a carotid intervention are registered in the DACI. As a consequence, no information is available on patients who suffered a stroke while waiting for CEA and were therefore no longer eligible for it. Registering these recurrent ischaemic events during the waiting time to carotid revascularisation is necessary to evaluate better the quality of care. Second, two factors associated with total delay to CEA identified from the previous studies are not registered in the DACI: type of index event (TIA or ischaemic stroke) and whether the patient was admitted after the index event until the CEA was performed. Lastly, it was assumed that the factors associated with hospital dependent delay are attributable to the hospitals, but it remains possible that patient factors, such as concerns about the procedure, contribute to the delay. However, it is suspected that this type of patient delay is only applicable in a small number of patients and that surgeons have a leading role in minimizing the waiting time even in these patients.

CONCLUSION

This study, with data from 8620 consecutive patients, forming a large nationwide prospective audit, identified that younger age, previous CEA, ocular symptoms as index event, and indirect referral were factors associated with hospital dependent delay. A subgroup analysis of patients with ocular symptoms showed that these patients are at higher risk of hospital dependent delay when they primarily present to ophthalmologists rather than neurologists. The number of CEA procedures at the hospitals was not identified as a factor for delay; however, high volume hospitals had more indirectly referred patients with similar hospital dependent waiting time, implying that optimisation of in hospital logistics is a crucial factor in reducing delay to CEA.

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CONFLICTS OF INTEREST

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2019.05.015.

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