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SYSTEMATIC REVIEW

A Systematic Review and Meta-Analysis of the Presentation and Surgical Management of Patients With Carotid Body Tumours

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WHAT THIS PAPER ADDS

This is the largest systematic review and meta-analysis detailing the presentation, management, and procedural complications following carotid body tumour (CBT) surgery. Although relatively rare, complications associated with CBT are not inconsiderable, especially in the more challenging Shamblin III CBTs where procedural stroke rates were about 4%, while cranial nerve injury rates approached 20%. The increasing morbidity associated with Shamblin III tumours must be considered during the consent process.

Objectives: The aim was to determine the mode of presentation and 30 day procedural risks in 4418 patients with 4743 carotid body tumours (CBTs) undergoing surgical excision.

Methods: This is a systematic review and meta-analysis of 104 observational studies.

Results: Overall, 4418 patients with 4743 CBTs were identified. The mean age was 47 years, with the majority being female (65%). The commonest presentation was a neck mass (75%), of which 85% were painless. Dysphagia, cranial nerve injury (CNI), and headache were present in 3%, while virtually no one presented with a transient ischaemic attack (0.26%) or stroke (0.09%). The majority (97%) underwent excision, but only 21% underwent pre-operative embolisation. Overall, 27% were Shamblin I CBTs; 44% were Shamblin II; and 29% were Shamblin III. The mean 30 day mortality was 2.29% (95% CI 1.79–2.93). The mean 30 day stroke rate was 3.53% (95% CI 2.91–4.29), while the mean 30 day CNI rate was 25.4% (95% CI 24.5–31.22). The prevalence of persisting CNI at 30 days was 11.15% (95% CI 8.42–14.64). Twelve series (544 patients) correlated 30 day stroke with Shamblin status. Shamblin I CBTs were associated with a 1.89% stroke rate (95% CI 0.92–3.82), increasing to 2.71% (95% CI 1.43–5.07) for Shamblin II CBTs and 3.99% (95% CI 2.34–6.74) for Shamblin III tumours. Twenty-six series (1075 patients) correlated CNI rates with Shamblin status: 3.76% (95% CI 2.62–5.35) for Shamblin I CBTs, 14.14% (95% CI 11.94–16.68) for Shamblin II, and 17.10% (95% CI 14.82–19.65) for Shamblin III tumours. The prevalence of neck haematoma requiring re-exploration was 5.24% (95% CI 3.45–7.91). The proportion of patients with a neck haematoma requiring re-exploration was not reduced by pre-operative embolisation (5.92%; 95% CI 2.56–13.08) vs. no embolisation (5.82%; 95% CI 2.76–11.88). Pre-operative embolisation did not reduce drainage losses (639 mL vs. 653 mL).

Conclusions: This is the largest meta-analysis of outcomes after CBT excision. Procedural risks associated with tumour excision were considerable, especially with Shamblin III tumours where 4% suffered a peri-operative stroke and 17% suffered a CNI.

Keywords: Carotid body tumour, Operative stroke, Cranial nerve injury

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INTRODUCTION

The carotid body is a small chemoreceptor organ located within the posteromedial aspect of the carotid bifurcation. Its physiological role relates to homeostasis of pH, pO_2, and pCO_2, which it controls through modulation of cardiovascular and respiratory function with the release of neurotransmitters as necessary. It is a highly vascular organ, receiving a rich arterial blood supply originating from branches mainly derived from the external carotid artery (ECA), most commonly the ascending pharyngeal branch. Carotid body tumours (CBTs), which are also termed chemodectomas, are rare neoplasms with a reported incidence

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of one in 30,000. However, they make up 65% of all head and neck paragangliomas.[1]

CBTs can be classified by aetiology or anatomy. The three recognised aetiological types are sporadic (the most common), familial, and hyperplastic. Hyperplastic CBTs are most commonly diagnosed in the context of chronic hypoxia, for example in patients living at high altitude or with chronic lung disease. Surgically, the anatomical classification described by Shamblin et al.[2] is the most clinically useful as it describes the extent to which the CBT envelopes the common carotid artery (CCA), the internal carotid artery (ICA), and the ECA and was designed to be a predictor of intra-operative technical difficulty (Fig. 1).

Many vascular surgeons have only a limited experience of treating CBTs, which can be associated with a not insignificant morbidity and mortality, especially peri-operative stroke and cranial nerve injury (CNI). To date, there has been no large scale systematic review and meta-analysis of outcome data to guide practice. The aim of the current study was to conduct a systematic review and meta-analysis of all published literature reporting the presentation and surgical outcomes of treating patients with CBT.

METHODS

Search strategy

A systematic review of the literature was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[3] The literature search was designed and completed by an NHS clinical librarian using the Healthcare Databases Advanced Search (HDAS) tool. The search strategy included the following keywords, relevant vocabulary and MESH terms: "carotid body", "carotid body tumour or tumor" and "paraganglioma". The databases interrogated were Medline, Embase, and the Cochrane library and the search was performed from inception to September 2017.

For the title, abstract, and full text article, screening was undertaken independently by three reviewers (F.P., B.H., V.R.). Only studies reporting outcome data for CBT surgery were included. Single case reports and case series of five or fewer patients were excluded together with unpublished, non-peer reviewed data. All other studies, regardless of methodology, were included, given the lack of randomised trials. Any disparity between the three reviewers was resolved firstly by discussion between the reviewers, and secondly by arbitration by A.R.N. Data extraction was conducted independently by the three reviewers, the results of which were then compared until a consensus was achieved.

Outcome measures

Primary measures of interest extracted from the literature were 30 day death; 30 day stroke; and 30 day CNI. Secondary measures included stratification of presentation, surgery, and outcome by Shamblin classification; post-

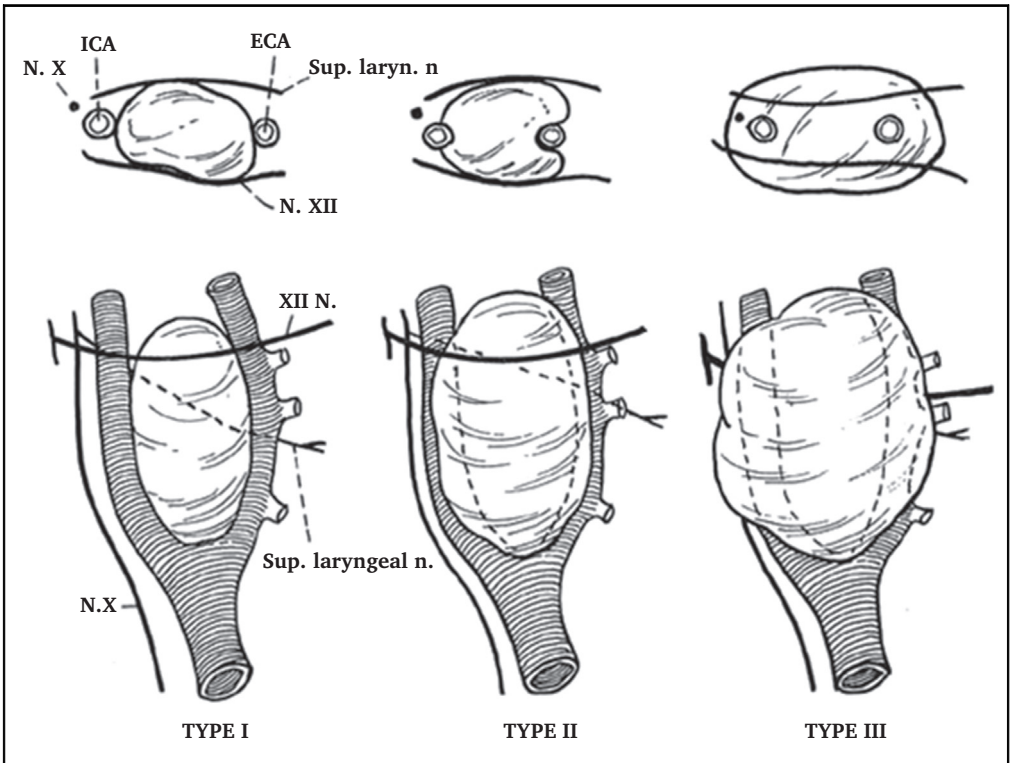

Figure 1. The Shamblin classification of the difficulty of surgical resection. Type I tumours are localised and easily resected. Type II includes tumours adherent or partially surrounding vessels. Type III tumours intimately surround or encase the vessels. Reproduced with permission from Hallett et al.[111] ICA = internal carotid artery; ECA = external carotid artery; N = nerve; sup. laryn. n. = superior laryngeal nerve.

operative haematoma formation, intra-operative blood loss; and bleeding complications stratified by whether pre-operative embolisation was utilised. Attempts were made to obtain and subsequently analyse descriptive data (where available), specifically mode of presentation, age, gender, laterality, functionality, histology, follow up, duration of CNI, and individual cranial nerves affected.

Statistical analysis

Following extraction of data on a digital spreadsheet, all statistical analyses were performed using the R package for Microsoft Windows (version 3.4). The collected data were then explored by the authors (A.S., V.R., A.R.N.) to assess whether meta-analytical methods could be applied to combine outcomes of interest and compare results between different groups of patients.

The proportions of patients developing each outcome of interest were combined using proportional meta-analysis. Interstudy heterogeneity was analysed using the I^2 statistic. This describes the percentage of total variation across studies because of heterogeneity, rather than chance or random error, and is a recognised method of quantifying heterogeneity in literature synthesis. An I^2 value $\geq$50% reflects significant heterogeneity owing to real differences in study populations, protocols, interventions, and outcomes. Based on the result of the I^2 statistic, a fixed effects model was used to combine studies if I^2 was $<$50% and a random effects model if I^2 was $\geq$50%. The weighted proportion and a 95% confidence interval (CI) is presented for each outcome of interest where proportional meta-analysis was performed. For continuous data, a weighted mean value was also calculated where possible.

When studies reported direct comparisons for certain variables of interest (e.g., comparison of rates of post-operative haematoma formation in cases that did and did not receive pre-operative embolisation), an odds ratio (OR) with 95% CI was calculated to compare outcomes between different groups of patients or presentations, but only when subsequent outcomes were reported in a uniform manner at specific identical time points in each study. ORs were combined using meta-analysis (fixed and random effects models, where appropriate). Studies with zero outcome events in every sub-group of patients were excluded ("zero/zero" events). A p value $<$ .05 was considered to be statistically significant.

Given the small sample size in the vast majority of the 104 studies, all of which were of observational nature, the number of "none or all" or missing data during follow up did not allow hazard or odds ratios to be calculated for post-operative events/outcomes based on Shamblin type. Furthermore, there was significant heterogeneity in both reporting outcomes and duration(s) of follow up, when reporting according to Shamblin type. After attempting to fit those data in a linear or log-linear regression model, it was deemed impossible given the amount of "all or none" events during follow up and the heterogeneity in terms of time points at which events were reported. Subsequently, direct comparisons between different Shamblin types were not performed.

RESULTS

Details of the full search strategy for this systematic review can be found in Appendix I. The initial search yielded 1007 articles (Fig. 2; PRISMA diagram), which was reduced to 511 after exclusion of duplicates and non-English language papers. These 511 papers were then screened for eligibility and a further 407 were excluded leaving 104 for inclusion in the qualitative and quantitative synthesis. All 104 were observational studies and there were no randomised controlled trials. Two studies[4,5] were prospective in design, while the remainder were retrospective.[6–107] The Newcastle–Ottawa scale was used to assess the methodological quality of each study (A.S., V.R.). Appendix II provides details of the 104 observational studies included in the syntheses, together with the principal characteristics, outcomes included, and the Newcastle–Ottawa scores. A total of 4418 patients and 4743 individual CBTs were included. The collective study period ranged from 1941 until 2015. Twenty-eight studies were completed entirely in the 20th century; a further 35 were completed before 2010, and 30 up to 2015 (the remaining 11 studies did not report their exact study period).

Demographics and mode of presentation

Table 1 details the main descriptive, demographic data. The weighted mean age of the patient cohort was 47.3 years, with the majority being female (65%). Bilateral tumours were reported in 9.6% of patients, while 4.1% were found to have malignant tumours following histological review of the resected specimen. Functional (catecholamine secreting) CBTs were reported in only 2.3% of patients.

Information on presenting symptoms was available in 92 studies (3458 patients). The most common presentation was a neck mass (75%). Of these, 86% of neck masses were painless and asymptomatic, while 16% were symptomatic (Table 2). The proportion of CNI, dysphagia, and headache, as presenting symptoms, was about 3% for each. Syncope/dizziness, vertigo, and tinnitus affected 1–2% of patients, while hardly any patients presented with either a transient ischaemic attack (0.26%) or stroke (0.09%).

Outcomes of surgical treatment

The majority of patients in the systematic review (97%) underwent surgical excision. Only a minority (21%) underwent pre-operative embolisation of ECA branches feeding the CBT. Using the Shamblin classification, 27% were Shamblin I tumours; 44% were Shamblin II, and 29% were Shamblin III. The weighted mean follow up period was 55 months (range of mean values 1–312 months).

Peri-operative death and stroke

Data on 30 day mortality, 30 day stroke, and 30 day death/stroke were reported in 99, 92, and 89 studies respectively.

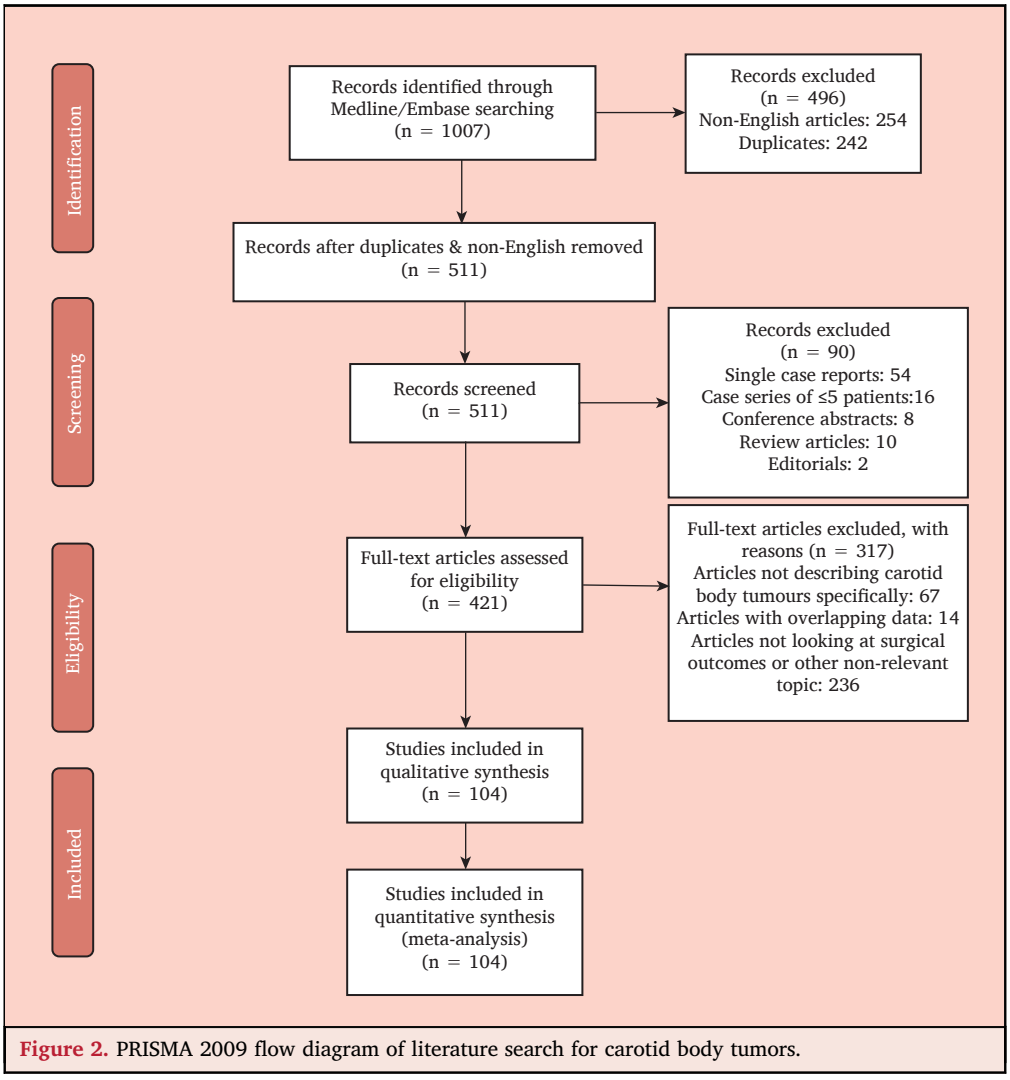

Figure 2. PRISMA 2009 flow diagram of literature search for carotid body tumors.

Table 1. Summary demographic and descriptive data of carotid body tumour patients (n = 104 analyzed studies)

Descriptor	Result	No. of studies reported	Total no. of patients
Median individual study period (range), years	15 (2 – 62)	93	4,114
Age, weighted mean, years	47.3	90	4,116
Age, range, years	9 – 94	97	3,632
Gender		101	4,383
Male	1,528 (34.9)		
Female	2,885 (65.1)		
Follow up period			
weighted mean, months	53.6	43	1,518
range, months	1 – 312	55	1,621
Proportion operated		104	4,418
Patients operated	4,285 (97.0)		
CBTs operated	4,588 (96.7)		
Bilateral CBTs	310 (9.6)	85	3,216
Malignant histology	114 (4.1)	63	2,806
Catecholamine secreting CBTs	17 (2.3)	21	726
Shamblin classified CBTs		64	2,785 (2,901 CBTs)
I	748 (27)		
II	1,229 (44)		
III	808 (29)		
Pre-operative embolisation	622 (20.8)	68	2,994

Data are *n* (%) unless otherwise indicated. CBT = carotid body tumour.

Table 2. Symptoms of carotid body tumor (92 studies, 3,458 patients)

Symptom	Proportion, %
Neck mass	75.3
Asymptomatic	86.0
Symptomatic	14.0
Cranial nerve palsy	3.5
Dysphagia	3.1
Incidental	3.1
Headache	2.6
Dysphonia	1.7
Syncope/dizziness	1.5
Other	1.5
Vertigo	1.3
Tinnitus	1.1
Transient ischaemic attack	0.3
Stroke	0.1

Details of the reported individual outcomes by study are shown in Appendix II. Table 3 shows that in 99 studies (4306 patients), the mean 30 day mortality was 2.29% (95% CI 1.79—2.93; $I^2 = 0\%$). In 92 studies (4061 patients), the mean proportion of patients developing a stroke at 30 days was 3.53% (95% CI 2.91—4.29; $I^2 = 0\%$). In 89 studies (4004 patients), the 30 day rate of death/stroke was 4.10% (95% CI 3.42—4.91; $I^2 = 3\%$).

Only 12 studies (544 patients) reported 30 day stroke rates, stratified for the patient's Shamblin status. Patients with a Shamblin I CBT incurred a 1.89% stroke rate at 30 days (95% CI 0.92—3.82) compared with 2.71% (95% CI 1.43—5.07) in patients with Shamblin II tumours and 3.99% (95% CI 2.34—6.74) in patients with Shamblin III tumours. If the cohort of patients who suffered a stroke after CBT excision and in whom the Shamblin status was known is now considered, the proportion of strokes following Shamblin III tumour excision was 60% vs. 25% for Shamblin II and 15% for Shamblin I tumours. Analysis of 30 day mortality stratified by Shamblin status was not possible owing to the very low numbers among too few studies that reported this outcome measure.

Table 4. Risk of cranial nerve injury after carotid body tumor excision (94 studies, 3608 operated patients)

Nerve injury	*n* (%)
CN XII	346 (9.6)
CN X	291 (8.1)
Horner's	103 (2.9)
CN VII	101 (2.8)
CN IX	77 (2.1)
Recurrent laryngeal	69 (1.9)
Superior laryngeal	56 (1.6)
CN XI	37 (1.0)

CN = cranial nerve.

Cranial nerve injury

Data on CNI were reported by 99 studies. Among these studies (4327 patients) the overall CNI rate was 25.4% (95% CI 24.5—31.33). Table 4 details the cranial nerves affected in 94 published series involving 3608 patients undergoing CBT excision. The commonest CNI involved the hypoglossal nerve (9.59%), while the vagus nerve (and/or its branches) was affected in 8.07% (recurrent laryngeal 1.9%; superior laryngeal 1.55%). A Horner's syndrome complicated 2.85% of tumour excisions; the mandibular branch of the facial nerve was affected in 2.8%, the glossopharyngeal nerve in 2.13%, and the accessory nerve in 1.03%. Fifty-nine series (2324 patients) reported whether CNIs were temporary or persistent. The prevalence of persisting CNIs at 30 days was 11.15% (95% CI 8.42—14.64), while the prevalence of minor/temporary CNIs was 20.4% (95% CI 17.38—23.79).

Table 3. Post-operative outcomes after surgical excision of carotid body tumor (according to 104 analysed studies)

Outcome	Proportion, % (weighted)	95% CI	I^2, %	Absolute % of events per group	No. studies reported	Total no. of patients
30 day death	2.2	1.79 − 2.93	0		99	4,306
30 day stroke	3.5	2.91 − 4.29	0		92	4,061
30 day stroke, stratified by Shamblin class					12	544
Shamblin I	1.9	0.92 − 3.82	0	15		
Shamblin II	2.7	1.43 − 5.07	0	25		
Shamblin III	4.0	2.34 − 6.74	25.8	60		
30 day death and stroke	4.1	3.42 − 4.91	3.0		89	4,004
Cranial nerve injury	25.4	22.36 − 28.70	74.1		99	4,327
Cranial nerve injury ± Horner's syndrome	27.8	24.49 − 31.33	75.0		99	4,327
Cranial nerve injury, stratified by Shamblin class					26	1,075
Shamblin I	3.8	2.62 − 5.35	0	7		
Shamblin II	14.1	11.94 − 16.68	43.9	39		
Shamblin III	17.1	14.82 − 19.65	36.9	54		
Cranial nerve injury[a]					59	2,324
Temporary	20.4	17.38 − 23.79	58.2			
Persistent	11.2	8.42 − 14.64	71.3			
Haematoma	5.2	3.45 − 7.91	50.5		28	1,269

CI = confidence interval.

[a] Weighted proportions are presented with 95 CIs and hence cannot be used to calculate other figures listed in this column, as in the case of temporary, persistent and total cranial nerve injury.

Twenty-six studies (1075 patients) reported the rate of CNI, stratified according to the Shamblin tumour classification. The prevalence of CNI after resection of Shamblin I CBTs was 3.76% (95% CI 2.62—5.35), increasing to 14.14% (95% CI 11.94—16.68) in patients with Shamblin II tumours and 17.10% (95% CI 14.82—19.65) in patients with Shamblin III tumours. Considering the cohort of patients who suffered a CNI after CBT excision and in whom the Shamblin status was known, the proportion of CNIs following Shamblin III tumour excision was 54%, vs. 39% for Shamblin II and 7% for Shamblin I tumours.

Bleeding complications

The prevalence of neck haematomas requiring re exploration was 5.24% (95% CI 3.45—7.91). Thirteen studies (420 patients) reported on whether pre-operative embolisation of ECA branches influenced re exploration for neck haematomas after CBT excision. There was no difference in the prevalence of re exploration for neck haematomas if patients had undergone pre-operative embolisation of ECA branches (5.92%; 95% CI 2.56—13.08), compared with patients who underwent CBT excision without pre-operative embolisation (5.82%; 95% CI 2.76—11.88) (OR 0.58 (95% CI 0.13—2.63); $p = .48$; I^2 28.5%) (Fig. 3). Sixteen series (472 patients) reported a non-significant difference in mean blood loss in patients undergoing CBT excision after pre-operative embolisation (639 mL; range of mean values 0—1123 mL), vs. 653 mL (range of mean values 110—855 mL) in patients who did not undergo pre-operative embolisation. Of the studies that reported bleeding complications, only one study reported data on anticoagulant usage, and reported no difference in haematoma rates based on this variable.[81]

DISCUSSION

CBT is a rare condition, and in this systematic review the mean number of patients per study was 42 over a median period of 15 years. Only 21 studies had a cohort of more than 50 patients, while only seven reported outcomes in more than 100 patients. The peak age for incidence was the fifth decade, about 10% were bilateral and two thirds of patients were female. Findings relating to clinical presentation were unsurprising with the commonest mode of presentation being a painless swelling. Of note, transient ischaemic attack and stroke were virtually never associated with CBT presentation.

Procedural risks after CBT excision in this meta-analysis were considerable and were higher than would normally be associated with carotid endarterectomy. Because most surgeons tend not to publish poor outcomes (i.e., introducing publication bias), procedural risk data in this meta-analysis (death, stroke, CNI) may actually be an underestimate of "real world" practice.

In a meta-analysis of CBT excision in 4061 patients (92 series), the mean 30 day rate of stroke was 3.53% (95% CI 2.91—4.29). The mean 30 day rate of death/stroke was 4.1% (95% CI 3.42—4.91) in 89 series reporting outcomes in 4004 CBT patients. There was a clear association between Shamblin status and rates of peri-operative stroke, with peri-operative stroke rates increasing as the tumour increasingly encased the CCA, ECA, and ICA. The mean 30 day stroke rate in 12 series reporting outcomes in 544 patients was 1.89% (95% CI 0.92—3.82) for excision of Shamblin I tumours, which have little encroachment onto the carotid vessels (Fig. 1) and which are usually easier to excise. The 30 day stroke rate increased to 2.71% (95% CI 1.43—5.07) following excision of Shamblin II tumours, where there is partial encroachment of the tumour. The highest peri-operative stroke rate was observed following excision of Shamblin III tumours (3.99%; 95% CI 2.34—6.74). These are typically the most difficult type of tumour to excise as they have already encroached to enclose the CCA, ICA and ECA. Table 3 also provides a breakdown of the proportions of strokes that occurred, stratified for Shamblin

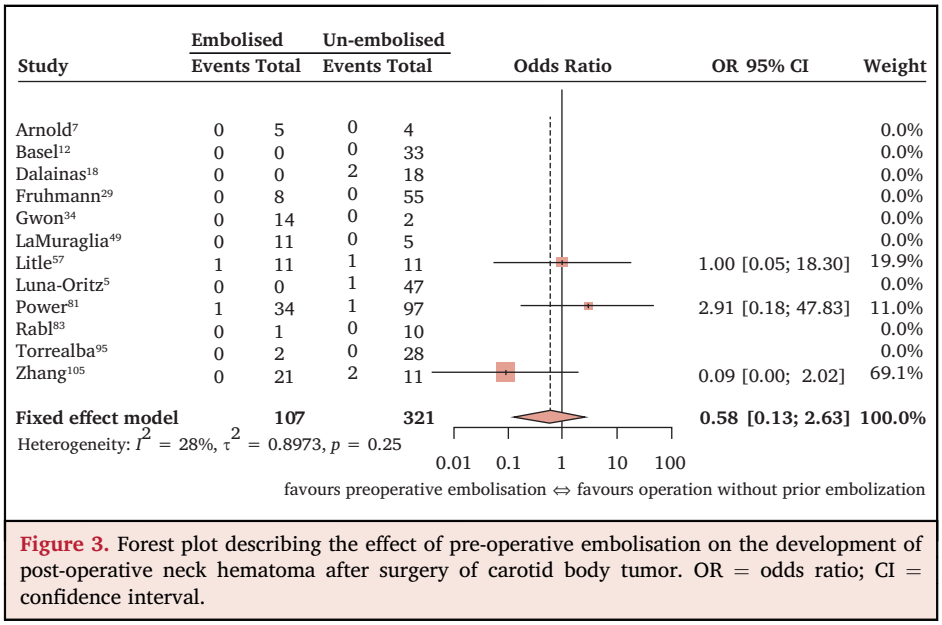

Figure 3. Forest plot describing the effect of pre-operative embolisation on the development of post-operative neck hematoma after surgery of carotid body tumor. OR = odds ratio; CI = confidence interval.

status. Sixty per cent of all observed strokes occurred in Shamblin III patients, with 25% of observed strokes occurring in Shamblin II patients and 15% in Shamblin I patients.

As might be expected, there was a similar finding with CNI. Overall (99 series, 4327 patients) the mean CNI rate was 25.4% (95% CI 22.36—28.7), with the most commonly affected nerves being the hypoglossal nerve (9.59%) and the vagus nerve (8.07%). It is not uncommon to find these cranial nerves (and occasionally the glossopharyngeal nerve) to be either adherent to the CBT or encased within part of the CBT. CNIs are not generally considered to represent "serious" complications, but they can be extremely disabling to the patient and should not be underestimated. Accordingly, it is essential that all patients being considered for CBT excision are counselled carefully about the heightened risk of suffering a post-operative CNI that may persist beyond 30 days in 11%. This is significantly higher than is usually observed following carotid endarterectomy.[108] The risk of CNI after excision of a Shamblin I CBT is low (3.76% (95% CI 2.62—5.35)). However, as the CBT increasingly encroaches and encases the CCA, ICA and ECA, the risks of CNI increase to 14.14% (95% CI 11.94—16.68) following excision of Shamblin II tumours and 17.10% (95% CI 14.82—19.65) after removal of Shamblin III tumours. Given the potential for publication bias in this meta-analysis, a CNI rate of at least 20% should probably be quoted to patients undergoing excision of a Shamblin III tumour. As with peri-operative stroke, Table 3 details a breakdown of the proportions of CNIs that occur, stratified for Shamblin status. Fifty-four per cent of all observed CNIs occurred in Shamblin III patients, with 39% of observed CNIs occurring in Shamblin II patients and 7% in Shamblin I patients.

There has been considerable debate about whether pre-operative embolisation of ECA feeder branches to the CBT reduces peri-operative bleeding complications. Two previous meta-analyses have evaluated the role of pre-operative embolisation[109,110] in reducing bleeding complications. Jackson et al.[109] reported that pre-operative embolisation decreased both operation time and intra-operative blood loss, while Abu-Ghanem[110] reported that no operative or post-operative advantages were conferred by pre-operative CBT embolisation. In the current meta-analysis, there was no difference in the prevalence of re exploration for neck haematomas where patients underwent pre-operative embolisation (5.92%; 95% CI 2.56—13.08) compared with patients who did not undergo pre-operative embolisation (5.82%; 95% CI 2.76—11.88) (OR 0.58 (95% CI 0.13—2.63); $p = .48$; I^2 28.5%) (Fig. 3). The reported low OR of 0.58 is an anomaly because of the fact that only three small studies reported comparative outcomes between the two modalities allowing the calculation and subsequent combining of ORs. Given the number of zero/zero events, calculation of ORs for the other studies was not possible. As such, the 95% CI is very wide (0.13—2.63) and the reported OR is not really representative of the observed incidence of events, which is why the percentage is reported. Given the reported I^2 (<50%) a fixed methods meta-analytical method was used, which is appropriate for this type of data. Furthermore, it is important to note that the third study was the main driver of this reported low OR, given the way the meta-analysis combined ORs. This is an inherent limitation of reporting ORs in small studies with several zero/zero events.

Sixteen series (472 patients) reported a non-significant difference in mean blood loss in patients undergoing CBT excision after pre-operative embolisation (639 mL) vs. 653 mL in patients who did not undergo pre-operative embolisation. This is a subject that would be best answered by an adequately powered randomised controlled trial (RCT).

This systematic review and meta-analysis has several limitations. Firstly, there were no RCTs and all of the studies were observational and mostly retrospective. Furthermore, their methodological quality was generally low with a mean Newcastle—Ottawa score of 3.8 and no study scoring higher than 5 out of a maximum 9. This introduces the potential for introducing reporting bias. Second, there was considerable heterogeneity in the standards of outcome reporting within the 104 published series, which is typical of predominantly retrospective, observational studies. Third, and something which has already been highlighted earlier, there is a tendency to not submit papers to journals where outcomes were poor. Accordingly, the procedural risk data reported in this meta-analysis may represent an underestimation of the true risk and this should be borne in mind when counselling patients about procedural risks.

Notwithstanding the limitations described, this is the largest meta-analysis of outcome data following excision of CBTs in the literature. Procedural risks are much higher than observed with carotid endarterectomy, especially cranial nerve injury. While peri-operative stroke/CNI risks are fairly low following excision of Shamblin I tumours, these risks significantly increase with Shamblin II and, especially Shamblin III tumours. This should be borne in mind when planning any excision. There is no evidence that routine pre-operative embolisation reduces bleeding complications or makes the operation easier, but there have been no randomised comparisons and there has been no stratification for pre-operative embolisation with regard to pre-operative Shamblin status.

CONFLICT OF INTEREST

None.

FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2018.10.038.

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