

Carotid artery disease and stroke during coronary artery bypass surgery

Stroke is a devastating complication during coronary artery bypass grafting. Screening may identify patients at highest risk. Surgical timing, sequence strategies and carotid stenting remain unresolved. Selective use of techniques could prevent adverse neurological sequelae while achieving complete myocardial revascularization.

Coronary artery bypass grafting is one of the most frequently performed operations in the western world. In the UK, 114 300 patients undergoing isolated first-time, elective coronary artery bypass grafting had a 30-day mortality of 1.5% in 2008, reduced from 2.2% in 2001 (Society for Cardiothoracic Surgery in Great Britain and Ireland, 2010). Refinement in myocardial protection and technique has improved the outcome of coronary artery bypass grafting.

Stroke remains one of the most devastating potential complications of coronary artery bypass grafting. Many have studied the incidence of stroke in this population, yielding estimates from 1.6% to 5.2% (Hogue et al, 1999). The reported incidence of new postoperative stroke from 2004–8 in the UK improved from 1.5% to 1% (Society for Cardiothoracic Surgery in Great Britain and Ireland, 2010). The risk of stroke following a review of 190 449 coronary artery bypass graft patients was 1.71% (95% confidence interval (CI) = 1.5–1.9%) (Naylor et al, 2002). Postoperative cognitive and neuropsychological dysfunction is more common, with an incidence that may exceed 60% (Mahanna et al, 1996). Initial 1-year data from the SYNTAX trial showed that stroke was significantly more likely with coronary artery bypass grafting (2.2% vs 0.6% with percutaneous coronary intervention; $P=0.003$) (Serruys et al, 2009).

Cerebral complications significantly increase operative mortality and severely limit postoperative recovery and quality of life (Reed et al, 1988). The profound impact of stroke after cardiac surgery is shown by the eightfold increase in hospital mortality (13% vs 1.6%) (Reed et al, 1988; Society for Cardiothoracic Surgery in Great Britain and Ireland, 2010) and the overall case mortality ranging from 13% to 23.1% (Roach et al, 1996). The length of intensive care unit stay is more than twice that of uncomplicated operations with an average of over 10 intensive care days and an average of 21 days of acute care (Roach et al, 1996; Naylor et al, 2002; Society for Cardiothoracic Surgery in Great Britain and Ireland, 2010). Patients who have a postoperative stroke also have poor medium-term survival (3-year survival of 72% with a postoperative stroke vs 93% with no stroke). The survival curves continue to diverge over time (Society for Cardiothoracic Surgery in Great Britain and Ireland, 2010). The psychological and emotional impact of a stroke on the patient

and family is devastating and the effect on the nursing and medical team is demoralizing. Resource consumption by the NHS after a stroke is substantial.

What are the relative stroke risks of carotid artery stenosis in coronary artery bypass graft patients?

There are diverse causes of stroke in coronary bypass patients and strategies exist to reduce risk in each area. Causes include extensive atherosclerosis of the aortic arch, carotid artery disease, air emboli and thromboembolism from the carotid arteries (Trehan et al, 1997).

Coronary artery disease is a part of more widespread atherosclerotic disease; there is a clear correlation between the extent of coronary disease and the incidence of carotid and peripheral vascular disease (Craven et al, 1990; Cirillo et al, 2001). Naylor et al (2002) found that the percentage of carotid artery stenosis in the coronary artery bypass graft population was 91% = <50% carotid artery stenosis, 5.5% = 50–99% unilateral carotid artery stenosis, 2.0% = 50–99% bilateral carotid artery stenosis, 1.5% = occlusion and contralateral carotid artery stenosis and overall 6% = 80–99% carotid artery stenosis or occluded.

Univariate analyses have identified numerous factors associated with an increased risk of stroke after coronary artery bypass grafting including age, prior stroke or transient ischaemic attack, aortic arch disease, carotid artery disease, peripheral vascular disease, carotid bruit, left main stem coronary disease, diabetes, smoking, hypertension, recent myocardial infarction and redo cardiac surgery. The heterogeneity of the factors suggests that the causes of post-coronary artery bypass graft strokes are multifactorial and interlinked (Ricotta et al, 1995).

Age greater than 65 years is one of the most commonly reported independent predictors of stroke (Tuman et al, 1992). For those <50 years the risk was <0.5% increasing to 2–3% for those aged 60–70 years and 8–9% for those over 80 years of age (Roach et al, 1996). Advanced age is

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not thought to be a cause of stroke per se but a marker of increased atherosclerotic burden (Borger et al, 2001). This association is important as the proportion of patients aged >65 years undergoing coronary artery bypass grafts has increased significantly over the last decade.

The prevalence of carotid bruit in 18 175 patients undergoing coronary artery bypass grafting was 9.93% and the risk of operative stroke in patients with a bruit was 5.6% (95% CI=3.7–7.5%) compared to 1.6% (95% CI=1.1–2.2%) in those with no bruit – an almost four-fold risk increase (Naylor et al, 2002). A carotid bruit is an important marker for advanced vascular disease generally and carotid and aortic arch disease in particular.

A history of cerebrovascular disease (transient ischaemic attack, prolonged reversible ischaemic neurologic deficit or stroke) is the strongest preoperative predictor of stroke risk, being 8.5% (95% CI=4.9–12.1%) compared to 2.2% (95% CI=1.4–3.1%) in neurologically asymptomatic patients – a near fourfold increase in risk of perioperative stroke (odds ratio 3.6, 95% CI=2.7–4.9, $P<0.0001$). This indicates pathological conditions in the cerebrovascular system or an underlying stenosis of one or both carotid arteries (D’Agostino et al, 1996).

Hypertension, diabetes and peripheral vascular disease are three more important predictors of stroke during coronary artery bypass grafting (odds ratio = 1.27, 1.31 and 1.39 respectively) (Bucerius et al, 2003). These patients are at increased risk of atherosclerotic embolization as well as impaired autoregulation of cerebral blood flow (Bentsen et al, 1975). Patients with coexistent carotid and coronary atherosclerosis are high risk for either surgery. Naylor et al (2002) reviewed 190 000 patients undergoing coronary artery bypass grafting and found that the stroke rate increased with the degree of carotid stenosis: 1.9% for the <50% stenosis subgroup, 6.7% for the 50–99% stenosis subgroup and 11.5% for the occlusion subgroup.

Is carotid screening warranted in coronary artery bypass graft patients?

Unrecognized carotid disease is generally present in elderly patients who are asymptomatic. Trehan et al (2000) found significant (>75%) carotid artery stenosis was present in 11.3% of asymptomatic patients older than 60 years of age who were screened with duplex before elective coronary artery bypass graft. In patients undergoing coronary artery bypass grafting D’Agostino et al (1996) found an incidence of carotid stenosis >50% in 20% of patients and >80% in 8%. Others have reported a 10.2% incidence of haemodynamically significant carotid stenosis (>80% stenosis), thus exposing the patient to the risk of perioperative neurological injury.

So should we screen for carotid disease before coronary artery bypass surgery to identify the subset of patients at highest risk of stroke as a result of carotid disease? History and physical examination are neither particularly sensitive nor specific for carotid disease. Sauve et al (1994) noted the sensitivity (63%) and specificity (61%) of neck auscul-

tation for detection of high grade carotid disease. The clinical correlates already mentioned point to an increased risk of significant carotid disease in patients having a coronary artery bypass graft. A patient aged 65 years or older, or with peripheral vascular disease, smoking history, previous transient ischaemic attack, previous stroke, left main coronary disease (Perler et al, 1988), carotid bruit, diabetes or hypertension requires further evaluation.

Screening for carotid disease implies that treatment can reduce subsequent stroke risk. The rationale for prophylactic carotid endarterectomy in asymptomatic patients came from two major prospective randomized trials: the Asymptomatic Carotid Atherosclerosis Study (Executive Committee for the Asymptomatic Carotid Atherosclerosis Study, 1995) and the Asymptomatic Carotid Surgery Trial which showed carotid endarterectomy was better than best medical treatment alone.

Well over 90% of the correlative power can be gained by screening those with at least three of these high-risk markers: bruit, age 65 years and older, diabetes, left main coronary disease, peripheral vascular disease, previous transient ischaemic attack, previous stroke and smoking history (*Table 1*) (Gott, 2001).

How should we manage concomitant coronary and carotid artery disease?

The Asymptomatic Carotid Atherosclerosis Study, which included patients with carotid artery stenosis 60–99%, showed a reduction in total ipsilateral strokes and death from 11% to 5.1% over 5 years compared with best medical therapy alone ($P<0.004$, absolute risk reduction=6%, relative risk reduction=53% – i.e. a 2% per year risk reduced to 1% per year risk). The North American Symptomatic Carotid Endarterectomy Trial Collaborators (1991) showed that in symptomatic patients with 70–99% carotid stenosis, carotid endarterectomy decreased the 2-year rate of ipsilateral stroke from 26% to 9% compared with best medical therapy alone ($P<0.001$, absolute risk reduction=17%). The international and national guidelines for the management of symptomatic and asymptomatic carotid artery stenosis are outlined in *Table 2*.

Surgical strategies are as controversial as the indications – optimal timing and sequence strategies are unresolved.

Table 1. High-risk markers for stroke: patients with at least three need further assessment

Bruit
Age 65 years and older
Diabetes mellitus
Left main stem disease
Peripheral vascular disease
Previous transient ischaemic attack
Previous stroke
Smoking history

Table 2. Guidelines for the management of symptomatic and asymptomatic carotid artery stenosis

	Symptomatic carotid artery stenosis (conditions required)	Asymptomatic carotid artery stenosis (conditions required)
American	Carotid artery stenosis 70–99%: carotid endarterectomy (recent 6 months) Carotid artery stenosis 50–69%: carotid endarterectomy (at least 5-year life expectancy, perioperative cerebrovascular accident/death < 6%) Carotid artery stenosis < 50%: medical	Carotid artery stenosis 60–99%: carotid endarterectomy (40–75 years old, at least 5-year life expectancy, perioperative cerebrovascular accident/death < 3%) Carotid artery stenosis < 60%: medical
English	Carotid artery stenosis 70–99%: carotid endarterectomy Carotid artery stenosis < 70%: medical	No guidance
Scottish	Carotid artery stenosis 50–99% male: carotid endarterectomy Carotid artery stenosis 70–99% female: carotid endarterectomy	Carotid artery stenosis >70%: carotid endarterectomy (most benefit <70 year old, male, bilateral)
American guidelines: American Academy of Neurology (2005); American Heart Association/American Stroke Association (2006); English guidelines: Intercollegiate Stroke Working Party (2008), National Institute for Health and Clinical Excellence (2008); Scottish guidelines: Scottish Intercollegiate Guidelines Network (2008)		

Despite over 30 years and more than 100 papers published on concomitant coronary artery and carotid artery disease only one small prospective randomized trial has been published. *Table 3* outlines guidelines for the management of concomitant carotid and coronary artery disease. Surgical strategies include unprotected – coronary artery bypass graft alone; staged – carotid endarterectomy then coronary artery bypass graft; reversed staged – coronary artery bypass graft then carotid endarterectomy; and combined carotid endarterectomy and coronary artery bypass graft. Coronary artery bypass graft alone confers excess risk: the stroke rate for unprotected coronary artery bypass graft with asymptomatic carotid artery stenosis was 2.2% (carotid artery stenosis <50%), 5.3% (carotid artery stenosis 50–99%) and symptomatic carotid artery stenosis was 8.5% (Naylor et al, 2003). Das et al (2000) reported that unprotected coronary artery bypass graft had stroke, death or combined stroke and death rates of 6.8%, 8.4% and 15.4% respectively, with the 10-year freedom from stroke or transient ischaemic attack of 98% with carotid endarterectomy and coronary artery bypass graft *vs* 75% with unprotected coronary artery bypass graft.

Borger et al's (1999) meta-analysis of 16 studies found the overall stroke and death rate was 9.5% for combined coronary artery bypass graft and carotid endarterectomy *vs* 5.7% for a staged procedure, whereas Das et al's (2000) review of 97 studies and 9000 patients showed that the overall stroke and death rate was 8.4% for the combined procedure *vs* 7.2% for a staged procedure. This was similar to the data from Naylor et al (2003) showing no significant difference in overall stroke and death rate at 11.5% for combined and 10.2% for a staged coronary artery bypass graft and carotid endarterectomy. Although reverse stage coronary artery bypass graft and carotid endarterectomy addresses the perioperative myocardial infarction risk with carotid endarterectomy, Hertzler and Lees (1981) reported an unacceptable stroke rate of more than 15%.

Carotid artery stenting is a valid alternative to carotid endarterectomy for treatment of cardiac patients. Van der Heyden et al (2007) reported a prospective study of 356 asymptomatic carotid artery stenosis patients who underwent carotid artery stenting before coronary artery bypass graft. The procedural success rate of stenting was 97.7%,

death and stroke rate was 4.8% and the combined death, stroke and myocardial infarction rate was 6.7%. Timaran et al's (2008) retrospective analysis showed that carotid stenting and coronary artery bypass graft patients had fewer major adverse events than those undergoing carotid endarterectomy and coronary artery bypass graft. Carotid stenting and coronary artery bypass graft patients had a lower incidence of postoperative stroke (2.4% *vs* 3.9%) and combined stroke and death (6.9% *vs* 8.6%) than the combined carotid endarterectomy and coronary artery bypass graft group ($P < 0.001$), although 30-day mortality was similar (5.2% *vs* 5.4%). Carotid stenting may provide safer carotid revascularization for coronary artery bypass graft patients but further studies are needed.

Conclusions

Stroke is a devastating complication of cardiac surgery. It affects about 2% of patients, a rate which has not changed much over the last three decades. Carotid artery disease should be suspected in cardiac surgery patients, especially the elderly. High grade carotid artery stenosis, both symptomatic and asymptomatic, increases the perioperative risk of stroke, with concomitant coronary and carotid disease being a marker of advanced atherosclerotic disease.

An aggressive, formalized system of screening high-risk patients should be organized at the individual, institu-

Table 3. International and national guidelines for the management of concomitant carotid and coronary artery disease

American Heart Association (2004)	Carotid endarterectomy is probably recommended as a staged or combined coronary artery bypass/carotid endarterectomy procedure, both symptomatic and asymptomatic, with unilateral and bilateral carotid artery stenosis > 80% Carotid screening probably recommended for patients: >65 years old, left main stem coronary disease, peripheral vascular disease, smoker, symptoms, carotid bruit
American Academy of Neurology (2005)	Data are insufficient to whether a staged or combined coronary artery bypass/carotid endarterectomy strategy is superior in concomitant carotid and coronary artery disease
Scottish Intercollegiate Guidelines Network (2008)	Routine carotid endarterectomy is not recommended for asymptomatic carotid artery stenosis

tional or team level and individualized for each patient. Well over 90% of the correlative power can be gained by screening those with at least three of the high-risk markers.

Even in asymptomatic carotid artery stenosis coronary artery bypass graft patients, where surgical management remains controversial, screening is important for risk stratification. Identifying these patients will allow pre-operative counselling on the increased risk of perioperative stroke, ensure epiaortic ultrasound is used to identify ascending aortic disease, avoid manipulation of the affected side perioperatively and guide the use of high perfusion pressures during cardiopulmonary bypass.

There is a trend towards fewer strokes with staged carotid endarterectomy than coronary artery bypass graft but the overall major risks show no significant difference with either staged or combined carotid endarterectomy and coronary artery bypass graft. The timing, sequence and method remain controversial, so a multidisciplinary approach involving cardiac surgery, vascular surgery and cardiology is needed for these patients.

Selective use of a variety of surgical techniques in high-risk patients could prevent adverse neurological sequelae while achieving complete myocardial revascularization. This will reduce short-term risks of treatment of either carotid or coronary disease alone, enhance long-term quality and length of life for these patients with advanced atherosclerosis and have significant resource savings. **BJHM**

Conflict of interest: none.

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KEY POINTS

- Stroke remains one of the most devastating potential complications of coronary artery bypass grafting, significantly increasing operative mortality and severely limiting postoperative recovery and quality of life.
- Further screening is recommended for those with at least three high-risk markers.
- Surgical strategies are as controversial as the indications with the optimal timing and sequence strategies unresolved; stenting may become a valid alternative to surgery.
- Selective use of a variety of techniques in this group of high-risk patients could prevent adverse neurological sequelae while achieving complete myocardial revascularization and enhancing the quality and length of life for these patients.

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