Impact of patients' age on short and long-term outcome after carotid endarterectomy and simultaneous coronary artery bypass grafting

Mona Salehi Ravesh 1*, Rene Rusch 2†, Christine Friedrich 2, Christoph Teickner 2, Rouven Berndt 2, Assad Haneya 2, Jochen Cremer 2 and Thomas Pühler 2

Abstract

Background: The purpose of this study was to investigate whether age has an effect on short and long-term outcome in patients who undergo simultaneous coronary artery bypass grafting (CABG) and carotid endarterectomy.

Methods: From 2005 to 2017, 186 consecutive elective patients underwent CABG and synchronous endarterectomy at our institution. Patients were retrospectively classified according to age into 2 groups: patients above 70 years (elderly group: n = 97, 76.1 ± 3.9 years) and patients below 70 years (younger group: n = 89, 63.2 ± 4.8 years).

Results: The European System for Cardiac Operative Risk Evaluation (EuroSCORE) II, 4.4% vs. 2.5%; p < 0.001) and Society of Thoracic Surgeons (STS) score (0.7% vs. 1.6%; p < 0.001) were significantly higher in the elderly group. Otherwise, there was no difference between the two groups concerning important preoperative risk factors or the intraoperative data. Postoperatively, the incidence of temporary dialysis was significantly higher in the elderly group (14.4% vs. 3.4%; p = 0.009). The rate of tracheotomy (16.5% vs. 2.2%; p = 0.001), of re-intubation (7.9% vs. 18.6%; p = 0.033) and drainage loss (600 ml vs. 800 ml; p = 0.035) was significantly higher in this elderly group. Neurological complications and 30-day mortality were comparable. Long-term survival was satisfactory for both groups. Nevertheless, 5-year survival rates (63% vs. 85%) were significantly lower in the elderly group (p = 0.003). Logistic regression analysis identified chronic obstructive pulmonary disease (COPD) and arrhythmia as significant risk factors for 30-day-mortality, but not age.

Conclusions: CABG in combination with synchronous endarterectomy can also be performed with satisfactory results in elderly patients.

Keywords: Coronary artery bypass grafting, Carotid endarterectomy, Age

Background

Coronary artery disease (CAD) is the most common type of heart disease and cause of mortality in the developed countries [1]. According to global and regional projections of mortality and burden of disease from 2002 to 2030, CAD will remain the leading cause of death in these countries for the next years to come [2]. In 2013, stroke was the second most common cause of death worldwide after ischemic heart disease [3]. Extracranial internal carotid artery stenosis is associated with around 8% of all ischemic strokes [4]. Significant coronary artery stenosis is a frequent additional finding in patients with repeat carotid artery stenosis (≥75%) [5]. Predictors of coincidence of CAD and carotid artery stenosis are advanced age, smoking, obesity, diabetes mellitus, arterial hypertension, and hyperlipidemia [6]. The presence of an additional carotid stenosis makes planning for the surgical treatment of CAD complicated.
are two surgical strategies (simultaneous and staged) for the treatment of concomitant carotid and coronary stenosis. On one hand, the staged surgical strategy is associated with a high risk of myocardial infarction if the carotid endarterectomy (CEA) or carotid artery stenting (CAS) is performed prior to coronary artery bypass grafting (CABG). On the other hand, this strategy is associated with an ischemic stroke if the CABG is carried out before the CEA/CAS [7, 8]. The period between the CEA/CAS and CABG is usually between 9 and 70 days [9]. The combined approach for CEA and CABG was reported for the first time in the 1970s [10, 11]. The simultaneous (“same-day”) strategy for CAS and CABG was first presented in the multicenter and prospective SHARP study as a new successful treatment approach in 2009. In the simultaneous strategy, patients underwent CABG immediately after CEA or CAS [12]. The optimal operative strategy for patients with concomitant carotid and coronary artery stenosis is still controversial and widely debated [13–15]. The CAS was introduced as a minimally invasive endovascular alternative to CEA, particularly for high-risk patients with an advanced age of >80 years [16]. Recently published results from the CREST and ACT1 trial have demonstrated similar long-term outcomes for CAS and CEA surgical approaches with respect to the risk of stroke, myocardial infarction, or death [17, 18]. Apart from the surgical strategies employed for the treatment of coronary and carotid stenosis, many studies have shown a significantly greater postoperative risk of stroke and death in patients with an advanced age than in younger patients [13, 19, 20].

The purpose of this study was to investigate whether age has an effect on outcome in patients who undergo simultaneous coronary artery bypass grafting and carotid endarterectomy.

Methods
Patients and study design
In our center, 186 consecutive elective adult patients had a simultaneous CABG and CEA between January 2005 and December 2017. Patients were divided into two groups: younger than and equal to or older than 70 years. The younger group consisted of 89 patients (63.2 ± 4.8 years) and the elderly group of 97 patients (76.1 ± 3.9 years).

In framework of our standard clinical concept, the extracranial carotid arteries of each patient is examined first using ultrasound, before a CABG operation. If there is a suspicious of carotid artery stenosis, the patient is additionally examined using computed tomography (CT) or magnetic resonance imaging (MRI). After the confirmation of the indication, the patient will prepared for the simultaneous surgical procedure.

The study population included all patients who underwent elective isolated CABG surgery with CEA. Exclusion criteria for this study were combined procedures or off-pump surgery.

All clinical data were collected prospectively on admission and during the in-hospital stay. We retrieved the data retrospectively by reviewing the hospital records. Primary end points were intraoperative and 30-day mortality, as well as long-term survival. Secondary end points were postoperative course (ventilation time, drainage loss, acute renal failure, neurologic complications). Patients were followed up directly in our outpatient clinic, seen by their general practitioner, or contacted directly by telephone or e-mail.

Detailed information about the used surgical technique and statistical analysis in this work are available in the Additional file 1.

Results
Demographics and preoperative characteristics
Relevant demographics and preoperative data of patients are given in Table 1. The patients in the elderly group were significantly older than the patients in the younger group (76.1 ± 3.9 vs. 63.2 ± 4.8, p < 0.001). The logistic EuroScore II (4.4% vs. 2.5%; p < 0.001) and STS score (1.6 vs. 0.7; p < 0.001) were significantly higher in the elderly group. The median creatinine value in the elderly group was significantly higher (1.1 vs. 0.9 mg/dl, p < 0.003). There was no difference between the two groups concerning the preoperative risk factors or clinical presentation.

Intraoperative data
The procedure time for the CEA in the younger group was significantly longer than that in the elderly group, but without clinical relevance (88 min vs. 80 min; p = 0.018). The intraoperatively administered number of red blood cell (RBC) units was higher in the elderly group, although this difference was not statistically significant (3.5 ± 2.3 vs. 2.3 ± 1.9, p = 0.052). Otherwise no significant differences were noted between the two groups with regard to intraoperative data. The number of distal anastomoses, the extracorporeal circulation time and the cross-clamp time were similar in both groups (Table 2).

Postoperative data
The incidence of postoperative temporary dialysis was significantly higher in the elderly group (14.4% vs. 3.4%; p = 0.009, Table 3). The 48-h drainage loss was significantly higher in the elderly group (800 [440; 1700] ml, vs. 600 [300; 1075] ml, p = 0.035). However, the postoperatively administered number of RBC units was similar in
| Variable                        | Total number N = 186 | Age < 70 years N = 89 | Age ≥ 70 years N = 97 | p-value |
|--------------------------------|----------------------|-----------------------|-----------------------|---------|
| Age (years)                    | 70.0 ± 7.8           | 63.2 ± 4.8            | 76.1 ± 3.9            | < 0.001 |
| Female gender, (%)             | 40 (21.5)            | 21 (23.6)             | 19 (19.6)             | 0.506   |
| BMI (kg/m²)                    | 27.7 ± 4.8           | 27.6 ± 4.4            | 27.8 ± 5.2            | 0.833   |
| Logistic EuroScore II (%)      | 3.4 (2.3;6.2)        | 2.5 (1.8;4.5)         | 4.4 (3.1;7.2)         | < 0.001 |
| STS-Score (%)                  | 1.0 (0.6;1.8)        | 0.7 (0.5;0.9)         | 1.6 (1.0;2.5)         | < 0.001 |
| COPD, n (%)                    | 23 (12.4)            | 12 (13.5)             | 11 (11.3)             | 0.657   |
| Creatinine (mg/dl)             | 1.07 (0.84;1.21)     | 0.9 (0.8;1.1)         | 1.1 (0.9;1.3)         | 0.003   |
| Dialysis, n (%)                | 3 (1.6)              | 1 (1.1)               | 2 (2.1)               | 0.622   |
| Diabetes mellitus, (%)         | 61 (32.8)            | 31 (34.8)             | 30 (30.9)             | 0.571   |
| IDDM, n (%)                    | 25 (13.4)            | 13 (14.6)             | 12 (12.4)             | 0.655   |
| Hyperlipidemia, (%)            | 137 (73.7)           | 67 (75.3)             | 70 (72.2)             | 0.630   |
| Arterial hypertension, (%)     | 159 (85.5)           | 73 (82.0)             | 86 (88.7)             | 0.199   |
| Pulmonary hypertension         | 12 (6.5)             | 4 (4.5)               | 8 (8.2)               | 0.298   |
| PAVK, n (%)                    | 54 (29.0)            | 28 (31.5)             | 26 (26.8)             | 0.485   |
| Carotid stenosis, right side, %| 1 = < 50% 57 (30.6)  | 26 (29.2)             | 31 (32.0)             | 0.523   |
| 2 = 50–69% 13 (7.0)            | 8 (9.0)              | 5 (5.2)               |                       |         |
| 3 = 70–89% 63 (33.9)           | 27 (30.3)            | 36 (37.1)             |                       |         |
| 4 = > 90% 53 (28.5)            | 28 (31.5)            | 25 (25.8)             |                       |         |
| Carotid stenosis, left side, n | 1 = < 50% 55 (29.6)  | 25 (28.1)             | 30 (30.9)             | 0.993   |
| 2 = 50–69% 16 (8.6)            | 8 (9.0)              | 8 (8.2)               |                       |         |
| 3 = 70–89% 71 (38.2)           | 34 (38.2)            | 37 (38.1)             |                       |         |
| 4 = > 90% 44 (23.7)            | 22 (24.7)            | 22 (22.7)             |                       |         |
| Symptomatic carotid stenosis, n| 48 (25.8)            | 26 (29.2)             | 22 (22.7)             | 0.309   |
| Neurological diseases, n (%)   | 10 (5.4)             | 7 (7.9)               | 3 (3.1)               | 0.198   |
| Cerebral ischemia, n (%)       |                       |                       |                       |         |
| TIA                            | 6 (3.2)              | 4 (4.5)               | 2 (2.1)               | –       |
| PRIND                          | 1 (0.5)              | 0                     | 1 (1.0)               | –       |
| Apoplexy                       | 30 (16.1)            | 18 (20.2)             | 12 (12.4)             | –       |
| Classification, n (%)          |                       |                       |                       |         |
| One-vessel disease             | 7 (3.8)              | 5 (5.6)               | 2 (2.1)               | –       |
| Two-vessel disease             | 21 (11.3)            | 8 (9.0)               | 13 (13.4)             | –       |
| Three-vessel disease           | 158 (84.9)           | 76 (85.4)             | 82 (84.5)             | –       |
| Angina pectoris, n (%)         | 124 (66.7)           | 60 (67.4)             | 64 (66.0)             | 0.836   |
| EF (%)                         | 55.0 ± 16.3          | 56.8 ± 16.3           | 53.4 ± 16.2           | 0.264   |
| Rhythm                         |                       |                       |                       |         |
| Atrial fibrillation, n (%)     | 25 (13.4)            | 3 (3.4)               | 22 (22.7)             | –       |
| Pacemaker, n (%)               | 4 (2.2)              | 1 (1.1)               | 3 (3.1)               | –       |
| Acute myocardial infarction, n | 41 (22.2)            | 16 (18.0)             | 25 (26.0)             | 0.187   |
| Previous heart surgery         | 9 (4.8)              | 6 (6.7)               | 3 (3.1)               | 0.315   |
| Previous PCI, n (%)            | 35 (18.8)            | 18 (20.2%)            | 17 (17.5%)            | 0.638   |
| CPR, n (%)                     | 1 (0.5)              | 1 (1.1)               | 0                     | 0.478   |
## Table 2 Operation and intraoperative findings

| Variable                          | Total N = 186 | Age < 70 years N = 89 | Age ≥ 70 years N = 97 | p-value |
|-----------------------------------|---------------|-----------------------|-----------------------|---------|
| **Urgency status of operations**  |               |                       |                       |         |
| Elective, (%)                     | 158 (84.9)    | 76 (85.4)             | 82 (84.5)             | –       |
| Urgent, (%)                       | 24 (12.9)     | 11 (12.4)             | 13 (13.4)             |         |
| Emergency, (%)                    | 4 (2.2)       | 2 (2.2)               | 2 (2.1)               |         |
| **Operated carotid side**         |               |                       |                       |         |
| 1 = right side, (%)               | 91 (48.9)     | 48 (53.9)             | 43 (44.3)             | 0.191   |
| 2 = left side, (%)                | 95 (51.1)     | 41 (46.1)             | 54 (55.7)             |         |
| **Carotid operation technique**   |               |                       |                       |         |
| 1 = Clamping, (%)                 | 113 (60.8)    | 54 (60.7)             | 59 (60.8)             | 0.983   |
| 2 = Shunt, (%)                    | 73 (39.2)     | 35 (39.3)             | 38 (39.2)             |         |
| **Procedure time for CEA (min)**  | 85.0 (61.5;180.0) | 88.0 (70.0;215.0)   | 80.0 (60.0;101.0)     | 0.018   |
| **Procedure time for CABG (min)** | 271.0 (230.0;317) | 271.0 (234.0;313.5) | 272.0 (225.0;319.8) | 0.844   |
| **Bypass time (min)**             | 126.4 ± 42.1  | 124.0 ± 41.0          | 128.6 ± 43.2          | 0.469   |
| **Aortic cross clamp time (min)** | 74.7 ± 35.0   | 70.1 ± 35.8           | 78.3 ± 34.1           | 0.157   |
| **Number of distal anastomoses**  | 3.0 (3.0;4.0) | 3.0 (3.0;4.0)         | 3.0 (2.0;4.0)         | 0.052   |
| **RBC, units**                    | 2.0 (2.0;4.0) | 2.0 (2.0;4.0)         | 2.0 (2.0;4.0)         | 0.040   |
| **FFP, units**                    | 0.0 (0.0;0.0) | 0.0 (0.0;0.0)         | 0.0 (0.0;0.0)         | 0.009   |
| **Platelet, units**               | 0.0 (0.0;1.0) | 0.0 (0.0;1.0)         | 0.0 (0.0;1.0)         | 0.033   |

*CABG coronary artery bypass grafting, CEA carotid endarterectomy, FFP fresh frozen plasma, RBC red blood concentrate

The significant p-value are marked in bold

## Table 3 Postoperative incidents and outcomes

| Variable                          | Total N = 186 | Age < 70 years N = 89 | Age ≥ 70 years N = 97 | p-value |
|-----------------------------------|---------------|-----------------------|-----------------------|---------|
| **Rhythm**                        |               |                       |                       |         |
| Atrial fibrillation (%)           | 18 (9.7)      | 5 (5.6)               | 13 (13.5)             | –       |
| Pacemaker (%)                     | 8 (4.3)       | 4 (4.5)               | 4 (4.2)               |         |
| ICU (days)                        | 2.0 (1.0;4.0) | 1.0 (1.0;4.0)         | 2.0 (1.0;6.0)         | 0.122   |
| Ventilation (hours)               | 17.0 (12.0;40.0) | 17.0 (12.0;24.5) | 17.5 (12.3;60.0)     | 0.290   |
| Temporary dialysis, (%)           | 17 (9.1)      | 3 (3.4)               | 14 (14.4)             | 0.009   |
| RBC, units                        | 2.0 (2.0;4.0) | 2.0 (2.0;4.0)         | 2.0 (2.0;4.0)         | 0.407   |
| FFP, units                        | 0.0 (0.0;4.0) | 0.0 (0.0;2.0)         | 0.0 (0.0;4.0)         | 0.326   |
| Platelet, units                   | 0.0 (0.0;0.0) | 0.0 (0.0;0.5)         | 0.0 (0.0;3)           | 0.990   |
| Drainage blood (ml)               | 700.0 (400.0;1500.0) | 600.0 (300.0;1075.0) | 800.0 (440.0;1700.0) | 0.035   |
| Pulmonary infections, (%)         | 16 (8.6)      | 4 (4.5)               | 12 (12.4)             | 0.052   |
| Perioperative myocardial infarction, (%) | 8 (4.3) | 1 (1.1) | 7 (7.2) | 0.066 |
| Reexploration for bleeding, (%)   | 11 (5.9)      | 7 (7.9)               | 4 (4.1)               | 0.280   |
| Sternal wound infection, (%)      | 9 (4.8)       | 4 (4.5)               | 5 (5.2)               | 1.000   |
| Re-intubation, (%)                | 25 (13.4)     | 7 (7.9)               | 18 (18.6)             | 0.033   |
| Tracheotomy, (%)                  | 18 (9.7)      | 2 (2.2)               | 16 (16.5)             | 0.001   |
| Stroke (CT proved), (%)           | 9 (4.8)       | 3 (3.4)               | 6 (6.2)               | 0.501   |
| 30d-MACCE, (%)                    | 17 (9.4)      | 5 (5.8)               | 12 (12.8)             | 0.111   |
| 30-day mortality (%)             | 9 (5.1%)      | 2 (2.3%)              | 7 (7.6%)              | 0.171   |

*CT computed tomography, ECMO extracorporeal membrane oxygenation, FFP fresh frozen plasma, ICU intensive care unit, IMC intermediate care station, MACCE major adverse cardiac and cerebrovascular events RBC: red blood concentrate

The significant p-value are marked in bold
both groups. Pulmonary infections occurred more frequently in the elderly group (12.4% vs. 4.5%; \( p = 0.052 \)). Consequently, the incidence rate of re-intubation (18.6% vs. 7.9%; \( p = 0.033 \)) and tracheotomy (16.5% vs. 2.2%; \( p = 0.001 \)) were significantly higher in the elderly group. Other factors determining ICU stay, such as postoperative neurological complications (6.2% vs. 3.4%; \( p = 0.501 \)) or sternal wound infection (7.2% vs. 3.4%; \( p = 0.335 \)), were comparable.

The 30-day mortality in the elderly group in Table 3 was slightly higher than in the younger group, but not significantly (7.6% vs. 2.3%, \( p = 0.171 \)). There was no difference between the two groups concerning 30-day major adverse cardiac and cerebrovascular events (MACCE, 12.8% vs. 5.8%, \( p = 0.111 \)).

Long-term survival was satisfactory in both groups. Nevertheless, one-year (78% vs. 92%), 3-year (75% vs. 87%) and 5-year (63% vs. 85%) survival rates were significantly lower in the elderly group (\( p = 0.003 \)) (Fig. 1). The Logistic regression analysis identified preoperative COPD and arrhythmia (atrial fibrillation or pacer) as significant risk factors for 30-day-mortality with odds ratios of 5.7 (CI 1.2–26.9) and 7.1 (CI 1.6–31.7), respectively (Table 4).

**Discussion**

In our single-center study, the effect of age on outcome in 186 patients who underwent simultaneous CABG and CAE was investigated. The patients were divided into two groups of younger than 70 and equal to or older than 70 years. The two groups were compared concerning their demographic, pre-, intra-, and postoperative data. There were no significant differences between the two patient groups concerning their pre- and intraoperative data, or their 30-day mortality and short-term major adverse cardiac and cerebrovascular events.

The optimal surgical approach (simultaneous or staged) for the treatment of patients with concomitant severe carotid and coronary stenosis is still the subject of controversial debate. In addition, with increasing age of the population, it is clinically relevant to clarify whether the postoperative risk of stroke and death in patients of an advanced age is higher than in younger patients.

In a larger analysis, Brott et al. [17] evaluated the outcomes of 2502 patients at 117 centers within the framework of the CREST study every 6 months for up to 10 years. These patients (69.0 ± 8.9 years) had been randomly assigned to stenting or endarterectomy. Brott et al. did not find a significant difference between patient groups with respect to the risk of periprocedural stroke, myocardial infarction, or death and subsequent ipsilateral stroke. The rate of postprocedural ipsilateral stroke also did not differ between groups.

Feldman and colleagues [13] compared trends and outcomes of three approaches to carotid revascularization in the CABG population when performed during the same hospitalization: 1) combined CABG and CEA, 2) staged CEA and CABG, and 3) staged CAS and CABG. A total of 22,501 patients were included in this study. 15% of these patients were equal to/older than 80 years. A higher number of patients (15,402, 68.4%) underwent combined CABG and CEA, followed by staged CABG and CEA (6297, 28.0%), and staged CABG and CAS (802, 3.6%). The risk of stroke was lower in patients from the first and second groups compared with
patients from the third group. The adjusted risk of death or stroke was similar in the 3 groups.

Sharma et al. [14] performed a meta-analysis of 12 studies comparing early outcomes of synchronous and staged approach of CABG and CAE. In these studies, a total of 17,469 and 7552 patients were included for the combined and staged approaches, respectively. The investigated endpoints were early mortality, major stroke, and major postoperative morbidity, myocardial infarction and stroke, and combined early mortality or stroke. Early events were compared using pooled estimates of risk ratios (random effects model) utilizing the inverse-variance method. The pooled analysis revealed no difference in early mortality ($p = 0.27$), postoperative stroke ($p = 0.07$), combined early mortality or stroke ($p = 0.11$), and combined endpoint of myocardial infarction or stroke ($p = 0.2$) between the two approaches.

The results of Brott et al., Feldman and Colleagues and Sharma et al. concerning the risk of periprocedural stroke, myocardial infarction are in line with our presented results.

In a retrospective single-center study, Wang et al. [21] reviewed the clinical data of octogenarians and younger patients to explore the association between age and outcome. Wang et al. reported that octogenarians are increasingly referred for elective cardiac surgery with more combined procedures (valve plus CABG or multiple valves) compared with younger patients ($p < 0.001$). The 30-day, 1-year and 5-year mortalities for octogenarians were 3.7, 10.8 and 29.0%, respectively. The octogenarians had higher adjusted 30-day ($p = 0.018$) and 1-year mortality ($p < 0.001$) compared to the younger group. Octogenarians had longer post-operative stays in ICU and hospital, and higher rates of ICU readmission ($p < 0.001$). After multi-variable adjustment, an age of older than or equal to 80 years was an independent predictor of death at 30 days and 1 year. In contrast to Wang et al., we did not find any differences between our patient groups concerning the post-operative stays in ICU and hospital, and also 30-day mortalities. But the one-year, 3-year and 5-year survival rates were significantly lower in our elderly group.

Alexander et al. [22] examined the predictors of inhospital mortality in octogenarians, compared with the predictors in younger patients, who underwent cardiac surgery at 22 centers. Alexander et al. reported that octogenarians undergoing cardiac surgery had fewer comorbid illnesses, but higher disease severity and surgical urgency than younger patients. Octogenarians had significantly higher in-hospital mortality after cardiac surgery than younger patients: isolated CABG (8.1% vs. 3.0%), CABG and aortic valve replacement (10.1% vs. 7.9%), CABG and mitral valve replacement (19.6% vs. 12.2%). In addition, octogenarians had twice the incidence of postoperative stroke and renal failure. The pre-operative clinical factors predicting CABG mortality in the very elderly were quite similar to those for younger patients. Of note, elderly patients without significant comorbidity had lower in-hospital mortality rates after CABG (4.2%) compared to those after combined CABG with aortic valve replacement (7%) and after combined CABG with mitral valve replacement (18.2%). Our elderly patient group showed a significant higher temporary dialysis, Drainage blood, re-intubation, and tracheotomy. Our data confirm the results of Alexader et al. regarding higher disease severity and surgical urgency in their elderly patient group.

Ohira et al. [23] investigated the relationship between age and both short- and long-term outcomes after off-pump CABG. They divided the patients into 3 groups: aged < 65 years (young), 65–74 years (early elderly), and > 75 years (late elderly), and retrospectively analyzed their clinical data. In-hospital mortality rates were similar among the groups. In logistic regression analysis, the risk factor for predicting major complications was the New York Heart Association (NYHA) classification ($p = 0.001$), and not age and preoperative myocardial infarction. The 10-year estimated rates free from cardiac death and cardiac events were not significantly different among the groups. In multivariate Cox models, independent risk factors predicting cardiac events were the NYHA classification, and ejection fraction, but not age. Ohira et al. reported that neither short- nor long-term cardiac outcomes after off-pump CABG are influenced by age at surgery.

**Conclusions**

In our study, CABG in combination with synchronous endarterectomy can be performed with satisfactory results, especially in the specific high-risk subgroup of patients of advanced age. The multivariate logistic regression analysis of clinically relevant parameters indicated that there is no significant effect of age on outcome in patients who undergo simultaneous CABG and CAE with single anesthesia. Based on our current results, we would recommend this surgical approach. However, further prospective, multi-center, and randomized clinical studies with a larger group of patients are required to investigate in detail the effect of age on patient outcome.
Limitations
The presented data were retrospective from a single center, and the sample size remains small.

Additional file

**Additional file 1:** Extended material and methods section. (DOCX 25 kb)

**Abbreviations**
- CAGB: Coronary artery bypass grafting
- CAD: Coronary artery disease
- CAS: Carotid artery stenting
- CEA: Carotid endarterectomy
- COPD: Chronic obstructive pulmonary disease
- NYHA: New York Heart Association

**Acknowledgements**
We acknowledge financial support from Land Schleswig-Holstein within the funding programme Open Access Publikationsfonds.

**Authors’ contributions**
Art, JC, and TP participated in conception and design of the study. RR, CT, RB obtained and organized the dataset. CF performed the statistical data analysis. AH and MS interpreted study data and drafted the article. All authors provided critical revisions of the article and approved the manuscript.

**Funding**
Not applicable.

**Availability of data and materials**
The dataset analyzed during the current study may be available from the authors on reasonable request.

**Ethics approval and consent to participate**
The Institutional Ethics Committee approved the study protocol and authorized its conduct and follow-up (D456/18). Individual patient consent for inclusion in the study was obtained.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare that they have no competing interest.

**Author details**
1Department of Radiology and Neuroradiology, University Hospital Schleswig-Holstein Campus Kiel, Arnold-Heller-Street 3, Building 41, 24105 Kiel, Germany. 2Department of Cardiovascular Surgery, University Hospital Schleswig-Holstein Campus Kiel, Arnold-Heller-street 3, Building 18, Kiel, Germany.

**Received:** 31 March 2019 **Accepted:** 3 June 2019
**Published online:** 15 June 2019

**References**
1. Tardif JC. Coronary artery disease in 2010. Eur Heart J Suppl. 2010;12:C2–C10.
2. Mathers CD, Loncar D. Projections of global mortality and burden of disease from 2002 to 2030. PLoS Med. 2006;3:e442.
3. Feigin VL, Norving B, Mensah GA. Global Burden of Stroke. Circ Res. 2017;120:439–48.
4. Flaherty ML, Kissela B, Khoury JC, Alwell K, Moomaw CJ, Woo D, et al. Carotid artery stenosis as a cause of stroke. Neuroepidemiology. 2013;40:36–41.
5. Faggioni GL, Curr GF, Ricotta JJ. The role of carotid screening before coronary artery bypass. J Vasc Surg. 1990;12:724–9 discussion 729-31.
6. Steinvil A, Sadah B, Bornstein NM, Havakuk O, Greenberg S, Arbel Y, et al. Impact of carotid atherosclerosis on the risk of adverse cardiac events in patients with and without coronary disease. Stroke. 2014;45:2311–7.
7. Dziertka K, Pieniazek P, Musialek P, Piatek J, Tekieli L, Podolec P, et al. Treatment strategies in severe symptomatic carotid and coronary artery disease. Med Sci Monit. 2011;17:RA91–7.
8. Santos A, Washington C, Rahbar R, Benzaid D, Muluk S. Results of staged carotid endarterectomy and coronary artery bypass graft in patients with severe carotid and coronary disease. Ann Vasc Surg. 2012;26:102–6.
9. Naylor AR, Mehta Z, Rothwell PM. A systematic review and meta-analysis of 30-day outcomes following staged carotid artery stenting and coronary bypass. Eur J Vasc Endovasc Surg. 2009;37:379–87.
10. Bernhard VM, Johnson WD, Peterson JJ. Carotid artery stenosis. Association with surgery for coronary artery disease. Arch Surg. 1972;105:637–40.
11. Oikos JE, MacManus Q, Starr A. Myocardial revascularization and carotid endarterectomy: a combined approach. Ann Thorac Surg. 1977;23:560–3.
12. Versaci F, Reimers B, Del Giudice C, Schofer J, Giacomini A, Saccà S, et al. Simultaneous hybrid revascularization by carotid stenting and coronary artery bypass grafting: the SHARP study. JACC Cardiovasc Interv. 2009;2:393–401.
13. Feldman DN, Swaminathan RV, Geleris JD, Okin P, Minutillo RM, Kishnani U, et al. Comparison of trends in hospital outcomes of concurrent carotid artery revascularization and coronary artery bypass graft surgery: the United States experience 2004 to 2012. JACC Cardiovasc Interv. 2017;10:286–98.
14. Sharma V, Deo SV, Park SJ, Joyce LD. Meta-analysis of staged versus combined carotid endarterectomy and coronary artery bypass grafting. Ann Thorac Surg. 2014;97:102–9.
15. Mackey WC, Rabbabz K, Bojar R, O’Donnell TF. Simultaneous carotid endarterectomy and coronary bypass: perioperative risk and long-term survival. J Vasc Surg. 1996;24:58–64.
16. Yadav JS, Wholey MH, Kuntz RE, Fayad P, Katzen BT, Mishkel GJ, et al. Protected carotid-artery stenting versus endarterectomy in high-risk patients. N Engl J Med. 2004;351:1493–501.
17. Brott TG, Howard G, Roubin GS, Meschia JF, Mackey A, Brooks W, et al. Long-term results of stenting versus endarterectomy for carotid-artery stenosis. N Engl J Med. 2011;364:1021–31.
18. Rosenfield K, Matsumura JS, Chaturvedi S, Riles T, Ansel GM, Metzger DC, et al. Randomized trial of stent versus surgery for asymptomatic carotid stenosis. N Engl J Med. 2011;364:1011–20.
19. Lucas ML, Bonamigo TP, Weber ELS, Luccheses FA. Combined carotid endarterectomy and coronary artery bypass grafting. Analysis of the results. Arq Bras Cardiol. 2005;85:412–20.
20. Minic C, Kobler L, Olsen PS, Andersson C, Jensen JS, Torp-Pedersen C. Risk of stroke after coronary artery bypass grafting: effect of age and comorbidities. Stroke. 2012;43:88–43.
21. Wang W, Bagshaw SM, Norris CM, Zibdawi R, Zibdawi M, MacArthur R. Association between older age and outcome after cardiac surgery: a population-based cohort study. J Cardiothorac Surg. 2012;7:57.
22. Alexander KP, Anstrom KJ, Muhsbaer LH, Grosswald RD, Smith PK, Jones RH, Peterson ED. Outcomes of cardiac surgery in patients or = 80 years: results from the National Cardiovascular Network. J Am Coll Cardiol. 2000;35:731–8.
23. Ohira S, Doi K, Numata S, Yamazaki S, Yamamoto T, Fukuishi M, et al. Does carotid endarterectomy reduce the risk of death in patients with severe coronary artery disease? J Thorac Cardiovasc Surg. 1990;99:663–7.
24. Salehi R, Rezaei H, Babamir K, Shamsi R, Sabeti M, Oveisnejad A. Carotid artery stenting in patients with CAD: a single-center experience. J Vasc Surg. 2014;59:1776–83.
25. Morgan TP, Feiring JD, Streif DB, Feeding JD, Streif DB, Feeding JD, Streif DB. Carotid artery stenosis as a cause of stroke. Neuroepidemiology. 2013;40:36–41.
26. Faggioni GL, Curr GF, Ricotta JJ. The role of carotid screening before coronary artery bypass. J Vasc Surg. 1990;12:724–9 discussion 729-31.
27. Steinvil A, Sadah B, Bornstein NM, Havakuk O, Greenberg S, Arbel Y, et al. Impact of carotid atherosclerosis on the risk of adverse cardiac events in patients with and without coronary disease. Stroke. 2014;45:2311–7.