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## Off-Pump Coronary Artery Bypass Surgery: Current Status

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Coronary revascularization was first performed on the beating heart. Later on the heart-lung machine facilitated the wide-spread application and allowed accurate anastomoses to be performed on a fibrillating or arrested heart. The contemporary beating heart surgery goes back to the original approach, thereby using appropriate technology and techniques that have allowed surgeons to perform high quality reproducible anastomoses. Beating heart surgery has once again established its place as an acceptable method for multi-vessel coronary revascularization.

Worldwide, approximately 30% of all surgical coronary revascularization procedures are performed on a beating heart (off-pump coronary artery bypass-OPCAB); in some countries they exceed 50%, while in some centers they even approach 99% of unselected cases. Several end-points have been analyzed from recent publications of the world literature, and are presented herein.

**KEY WORDS:** *coronary angioplasty;  
drug eluting stents; coronary bypass  
surgery*

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### COMPLETENESS OF REVASCULARIZATION

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A total of 200 unselected patients referred for elective coronary artery bypass grafting (CABG) were randomly assigned to undergo off-pump surgery with an Octopus tissue stabilizer or conventional CABG with cardiopulmonary bypass by a single surgeon [1]. The number of grafts performed per patient (3.39+1.04 for off-pump vs 3.40+1.08 for on-pump) and the index of completeness of revascularization (number of grafts performed/number of grafts intended, 1.00+0.18 for off-pump, 1.01+0.09 for on-pump) were similar. Combined hospital and 30-day mortalities and stroke rates were similar. Postoperative myocardial serum enzyme measures were significantly lower after off-pump CABG, suggesting less myocardial injury. Postoperative indices showed significantly less coagulopathy after off-pump surgery. Patients undergoing off-pump surgery received fewer units of blood, were more likely to avoid transfusion altogether, and had a higher hematocrit at discharge. More patients undergoing off-pump surgery were extubated in the operating room and within 4 hours. Postoperative length of stay was shorter for off-pump procedures (5.1+6.5 days for off-pump vs 6.1+8.2 days for on-pump, P=0.005).

The authors concluded that off-pump coronary bypass compared with on-pump achieved similar completeness of revascularization, similar in-hospital and 30-day outcomes, shorter length of stay, reduced transfusion requirement, and less myocardial injury.

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### EARLY MORBIDITY AND MORTALITY

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In a consecutive series of 3333 CABG patients operated in a single institution,

1593 patients were operated on-pump and 1740 patients off-pump [2]. The 3-month survival did not differ between the two groups (96.7% vs 95.9%), but the 8-day freedom from stroke did (99.4% vs 98.5%;  $P=0.004$ ). The hospital discharge was significantly influenced by the OPCAB approach for the total group ( $P=0.02$ ) as well as for the patients with EuroSCORE $>8$  ( $P=0.01$ ).

The authors concluded that larger datasets are required to obtain statistical significance for the observed mortality, stroke and dialysis reductions (20%/30%/60%). Subsets with fewer patients but higher risk identified risk-reducing effects for stroke. Hospital stay was shortened by the OPCAB approach.

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**TWO-YEAR SURVIVAL AND OTHER  
CARDIAC EVENTS**

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Between 1997 and 1999 Angelini et al randomized 200 patients to off-pump and 201 patients to on-pump coronary surgery [3]. Data analyses from all these patients showed lesser risk with off-pump compared with on-pump surgery for atrial fibrillation (-25%), chest infection (-12%), inotropic support (-18%), need for blood transfusion (-31%), and hospital stay longer than 7 days (-13%). During follow-up (14-25 months), all cause mortality was 2% vs 3%, and the incidence of deaths or cardiac-related events was 17% vs 21%.

The authors concluded that off-pump coronary surgery significantly lowered in-hospital morbidity without compromising outcome in the first 1-3 years after surgery compared with conventional on-pump coronary surgery.

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**BRAIN INJURY AND COGNITIVE  
DYSFUNCTION**

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Neurocognitive testing to detect stroke and brain scanning to assess cerebral perfusion and transcranial Doppler to detect cerebral microemboli were performed in 60 patients randomized between on- and off-pump CABG [4].

The authors concluded that OPCAB was associated with a significant reduction in intraoperative cerebral microemboli (transcranial Doppler), significantly better postoperative brain perfusion (SPECT) and improved neurocognitive performance at 2 weeks and 1 year postoperatively.

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**EARLY STROKE**

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Among 700 consecutive patients undergoing multi-vessel off-pump CABG, 429 patients undergoing aortic no-touch technique were compared with 271 patients in whom partial aortic clamps were applied [5]. The frequency of detected

atherosclerotic aortic disease was higher in the no-touch group (17.4% vs 5.1%,  $P < 0.0001$ ). The incidence of stroke (0.2% vs 2.2%,  $P=0.01$ ) was significantly lower in the no-touch group (1/429). Logistic regression identified partial aortic clamping as the only independent predictor of stroke, increasing this risk 28-fold.

The authors concluded that avoiding partial aortic clamping during off-pump CABG provides superior neurologic outcome. Thus, this technique is recommended whenever technically feasible.

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**MINOR MORBIDITY – ATRIAL  
FIBRILLATION**

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Meta-analysis of all randomized and propensity score matched studies from 2001-2003, studying atrial fibrillation in a generalized population, indicated that OPCAB reduced by 40% the incidence of post-operative atrial fibrillation [6]. However, when only studies of high-quality were considered, no significant difference could be detected.

The authors concluded that although OPCAB may reduce the incidence of post-operative atrial fibrillation in a generalized population (age $<70$  years), this finding is not clearly supported by high-quality randomized trials.

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**HOSPITAL MORTALITY AND RISK OF  
BLEEDING IN FEMALE PATIENTS**

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Women have consistently higher mortality and morbidity than men after CABG. Whether elimination of cardiopulmonary bypass and performance of CABG off-pump (OPCAB) have a beneficial effect specifically in women has not been defined. In a study of 21 902 consecutive female patients who underwent isolated CABG, a total of 7376 women were able to be successfully matched [7]. Multivariate logistic regression revealed that women undergoing on-pump surgery had a 73.3% higher mortality ( $P=0.002$ ) and a 47.2% higher risk of bleeding complications ( $P=0.019$ ).

The authors concluded that in a retrospective analysis of women undergoing CABG, computer-matched to minimize selection bias, off-pump surgery led to decreased mortality and morbidity including bleeding complications.

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**IN-HOSPITAL AND 1-YEAR RESOURCE  
UTILIZATION**

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In a meta-analysis of 37 randomized trials (3369 patients) [8] of off-pump CABG versus conventional CABG, no significant differences were found for 30-day mortality, myocardial infarction, stroke, renal dysfunction, intraaortic balloon pump,

wound infection, rethoracotomy, or reintervention. However, off-pump CABG significantly decreased atrial fibrillation, transfusion, inotrope requirements, respiratory infections, ventilation time, intensive care unit stay, and hospital stay. Patency and neurocognitive function results were inconclusive. In-hospital and 1-year direct costs were generally higher for on-pump versus off-pump CABG.

The authors of this meta-analysis concluded that mortality, stroke, myocardial infarction, and renal failure were not reduced in off-pump CABG, but selected short-term and mid-term clinical and resource outcomes were improved (15-35%) compared with conventional CABG.

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#### ECONOMIC COSTS IN A EUROPEAN ENVIRONMENT

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In a multicenter, randomized trial, 139 patients were randomly assigned to on-pump surgery and 142 to off-pump surgery [9]. Cardiac outcome and cost effectiveness were determined one year after surgery. At one year, the rate of freedom from death, stroke, myocardial infarction, and coronary reintervention was 90.6% after on-pump surgery and 88% after off-pump surgery. Graft patency in a randomized subgroup of patients was 93% after on-pump surgery and 91% after off-pump surgery. On-pump surgery was associated with \$1,839 in additional direct costs per patient (\$14,908 vs. \$13,069--a difference of 14.1%) and an increase in quality-adjusted years of life of 0.83 as compared with 0.82. Off-pump surgery was more cost effective than on-pump surgery in 95% of bootstrap estimates.

The authors concluded that in low-risk patients, there was no difference in cardiac outcome at one year between those who underwent on-pump bypass surgery and those who underwent off-pump surgery. Off-pump surgery was more cost effective.

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#### CONCLUSIONS

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- Complete and arterial coronary surgery off-pump is performed across the world on a daily basis mostly without patient-selection.

- Evidence-building is frequently limited by low prevalence of mortality and morbidity in on-pump surgery, patient-selection bias and unstructured OPCAB approaches. Power calculations mandate very large unselected cohorts.
- Coronary surgery off-pump reduces, after adjustment for variability in risk, early mortality and most major morbidity events: cognitive dysfunction, stroke and postoperative bleeding.

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