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CLINICAL RESEARCH

Results of elective cardiac surgery in patients with severe obesity (body mass index ≥ 35 kg/m²)

Résultats de la chirurgie cardiaque programmée chez les patients avec une obésité sévère (indice de masse corporelle ≥ 35 kg/m²)

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Morbidity;
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Summary
Background. — The increasing number of obese patients eligible for cardiac surgery requires risks and benefits to be balanced in this population.
Aims. — To study the results of cardiac surgery in severely obese patients (body mass index [BMI] ≥ 35 kg/m²).
Methods. — In this retrospective study of 3564 patients undergoing elective cardiac surgery between 2004 and 2012, the population was divided into two groups: BMI 20—34.9 kg/m² (n = 3282) and BMI ≥ 35 kg/m² (n = 282). Patients with BMI < 20 kg/m² were excluded due to the well-known increased mortality risk. The primary endpoint was 90-day mortality. A multivariable analysis was performed to identify prognostic factors.
Results. — Among our patients, 58.2% and 27.7% underwent isolated coronary or valvular surgery, respectively; 9.7% had combined valvular and coronary surgery and 4.4% had other procedures. Severely obese patients were younger: 62.5 ± 9.3 years vs 67.8 ± 10.7 years (P = 0.0001). Overall 90-day mortality was 4.0%. Severe obesity did not influence postoperative mortality. In the multivariable analysis, the interaction between preoperative renal failure and severe obesity was an important mortality prognostic factor (hazard ratio: 11.17; P = 0.03).

Abbreviations: BMI, body mass index; CPB, cardiopulmonary bypass; GFR, glomerular filtration rate; HR, hazard ratio.

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Mediastinitis rates were similar between groups in non-diabetic patients; in diabetic patients, severe obesity was associated with higher mediastinitis rates ($P = 0.002$). Superficial wound infections were higher in severely obese patients ($P = 0.003$).
Conclusion. — Elective cardiac surgery in severely obese patients was not associated with increased perioperative morbimortality, but had a higher superficial wound infection risk. Nevertheless, severe obesity itself should not be a contraindication to elective surgery.
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MOTS CLÉS
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Cardiaque

Résumé
Contexte. — L'augmentation des patients obèses éligibles à la chirurgie cardiaque nécessite de mieux étudier la balance bénéfices—risques.
Objectif. — Étudier les résultats de la chirurgie programmée chez les patients obèses sévères (indice de masse corporelle [IMC] $\geq 35\,kg/m^2$).
Méthodes. — Il s'agit d'une étude rétrospective de 3564 patients opérés entre 2004 et 2012. La population a été divisée en deux groupes : IMC : 20—34,9 kg/m^2 ($n = 3282$) et IMC $\geq 35\,kg/m^2$ ($n = 282$). Les patients avec un IMC < 20 kg/m^2 ont été exclus en raison d'un surrisque bien établi dans la littérature. Le critère de jugement était la mortalité à 90 jours.
Résultats. — Respectivement, 58,2 % et 27,7 % des patients ont eu une chirurgie coronarienne ou valvulaire ; 9,7 % une chirurgie combinée et 4,4 % d'autres procédures. Les patients obèses sévères étaient plus jeunes : 62,5 ± 9,3 ans vs 67,8 ± 10,7 ans ($p = 0{,}0001$). La mortalité à 90 jours était de 4,0 % et non influencée par l'obésité sévère. L'association insuffisance rénale préopératoire et obésité sévère était de mauvais pronostic (HR : 11,169 ; $p = 0{,}03$). Les taux de médiastinite étaient comparables entre les groupes, chez les non-diabétiques, alors que chez les diabétiques l'obésité sévère était associée à plus de médiastinites ($p = 0{,}002$). Les infections des cicatrices étaient plus élevées chez les patients obèses sévères ($p = 0{,}003$).
Conclusions. — La chirurgie cardiaque programmée chez des patients obèses sévères n'accroît pas la morbi-mortalité périopératoire. Elle présente un risque plus élevé d'infection de la cicatrice. Néanmoins, l'obésité sévère en soi ne devrait pas être une contre-indication à cette chirurgie.
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Background

Recent data from the World Health Organization showed that worldwide obesity has nearly doubled since 1980 [1]. In 2008, 35% of adults (> 1.4 billion) aged ≥ 20 years were overweight and 11% (> 200 million men and nearly 300 million women) were obese. Being overweight/obese is nowadays the fifth leading risk of global death and at least 2.8 million adults die each year as a result of being overweight or obese.

The proportion of obese patients eligible for cardiac surgery is following the same upwards trend, which raises the issue of the perioperative risk of this population. Low body mass index (BMI < 20 kg/m^2) is an independent factor that affects morbidity and mortality negatively after cardiac surgery [2,3]. On the other hand, the relationship between obesity and operative outcomes is unclear. Some authors have reported that obesity negatively affects operative mortality in patients undergoing valvular surgery [4], while others have suggested the existence of an 'obesity paradox', with such patients having a better survival rate than normal-weight patients [5,6].

The consequence of severe obesity (BMI ≥ 35 kg/m^2) in perioperative care after cardiac surgery is an interesting issue. The EuroSCORE risk calculation in this patient group might be incomplete in predicting operative mortality, as it does not take into account the weight of the patients. The present study aims to evaluate perioperative morbidity and mortality in severely obese patients undergoing elective cardiac surgery.

Methods

Population

This was a retrospective study carried out using a prospective database of 3564 patients undergoing elective cardiac surgery between January 2004 and December 2012. All patients gave written consent to inclusion of their medical information in our institutional database and to the use of this information for research purposes. The study was approved by the Institutional Review Board of the French Society of Thoracic and Cardio-Vascular Surgery (CERC-SFCTCV-2013-8-2-22-12-38-HyII).

Patients were divided into two groups according to their BMI: group I ($n = 3282$), $20\,kg/m^2 \leq BMI \leq 34.9\,kg/m^2$; group II ($n = 282$), BMI ≥ 35 kg/m^2. Patients with a BMI < 20 kg/m^2 were deliberately excluded due to their established increased mortality risk, as reported unambiguously in the literature. Overweight ($25\,kg/m^2 \leq BMI \leq 29.9\,kg/m^2$) and obese ($30\,kg/m^2 \leq BMI \leq 34.9\,kg/m^2$) patients were pooled with normal-weight patients ($20\,kg/m^2 \leq BMI \leq 24.9\,kg/m^2$), and severely obese patients ($35\,kg/m^2 \leq BMI \leq 39.9\,kg/m^2$) were pooled with morbidly obese patients ($BMI \geq 40\,kg/m^2$).

Preoperative renal function was estimated by glomerular filtration rate (GFR), calculated using the Cockcroft-Gault formula. A patient was considered to have preoperative chronic renal failure when the GFR was < 60 mL/min, and GFR was used as a dichotomous variable in further statistical analyses.

Operative management

During the 8-year study period, patients were operated on by three senior surgeons. All patients were monitored routinely in the operating room during cardiac surgery. Cannulation techniques and cardiopulmonary bypass (CPB) were conducted as usual. Myocardial protection was achieved by antegrade cold blood cardioplegia repeated every 30 minutes. In coronary patients, internal thoracic arteries were harvested in a skeletonized fashion by all surgeons. Sternal closure was done in a similar fashion in the two groups, mostly with seven simple wires. After the surgical procedure, patients were monitored in an intensive care unit (ICU) for at least 24 hours. Strict control of glycaemia (< 1.6 g/L) was maintained during the first two postoperative days, by means of an intravenous insulin perfusion. Thereafter, preoperative diabetic treatment (subcutaneous insulin and/or oral antidiabetics) was progressively reintroduced. All patients underwent a transthoracic echocardiogram before discharge, to confirm the absence of pericardial effusion.

Postoperative outcomes

Operative mortality included all patients who died within 90 days after surgery. Wound infection was defined as a bacteriologically positive collection in the presternal surgical site without sternal involvement or fracture. Mediastinitis was defined as the presence of a bacteriologically positive collection in the anterior mediastinum, behind the sternum, or bacteriologically positive samples from the sternum. All patients had a medical consultation with their surgeon 6 months after the operation. In our database, this marked the end of follow-up, giving us information only about postoperative and short-term outcomes.

Statistical analysis

Analyses were conducted using SAS software (SAS version 9.2; SAS Institute Inc., Cary, NC, USA). Continuous variables are expressed as means ± standard deviations or medians (interquartile ranges), as appropriate. Categorical variables are presented as absolute numbers and percentages. The comparison between severely obese patients ($BMI \geq 35\,kg/m^2$) and patients with a BMI between $20\,kg/m^2$ and $35\,kg/m^2$ was made using Student's *t* test for means of continuous variables, and the Chi^2 test or Fisher's exact test, as appropriate, for proportions of categorical variables.

Event-free survival curves were estimated using the Kaplan—Meier method and compared using the log-rank test. Median follow-up time was estimated with the reverse Kaplan—Meier method. Univariate Cox analyses were performed to identify independent predictors of an event (mediastinitis, wound infection and death were considered one at a time, mediastinitis and wound infection being censored at the time of death). As the main aim of this article was to study the predictive value of severe obesity, interactions between severe obesity and the other covariates were systematically tested, by comparing models with interactions with models without interactions using likelihood ratio tests. Owing to a significant interaction between severe obesity and diabetes for the hazard of mediastinitis, wound infection and death, analyses were done separately for non-diabetic and diabetic patients. The log-linearity assumption for continuous variables and the proportional hazard assumption were tested by Kolmogorov-type supremum tests as implemented in PROC PHREG in SAS software (SAS version 9.2; SAS Institute Inc., Cary, NC, USA) and inspected visually with residual plots. In case of violation of the former assumption, the continuous variable was dichotomized, the cut-off value being established visually; in case of violation of the latter assumption, a piecewise model was used to model the hazard ratio (HR) as a step function of time. Multivariable Cox models were built using best subset selection and were selected using Schwarz's Bayesian criterion, Harrell's c-statistic as a measure of calibration and Kent and O'Quigley's ρ^2 as a measure of discrimination. A two-tailed type I error rate < 0.05 was considered for statistical significance.

Results

Preoperative and perioperative characteristics

During the study period, 3849 patients (mean BMI $27.1 \pm 5.2\,kg/m^2$) underwent elective cardiac surgery in our department. Of these patients, 3564 had a $BMI \geq 20\,kg/m^2$ and were included for further analysis. Preoperative patient data are summarized in Table 1. The whole cohort of patients had a mean age of 67.3 ± 10.6 years and most were men (71.9%). Overall, 58.2% and 27.7% of the patients had isolated coronary or valvular surgery, respectively; 9.7% had combined valvular and coronary surgery and 4.4% had other procedures. Table 2 summarizes the perioperative data in the different groups. There was no difference in the number of harvested internal thoracic arteries between the groups ($P = 0.08$; Table 2). Similarly, this number did not differ between diabetic and non-diabetic patients in the severely obese group ($P = 0.10$).

Postoperative morbidity and mortality

For the whole cohort, the median durations of ventilation, ICU and total hospital stay were 6 (4—8) hours, 1 (1—2) days and 8 (7—9) days, respectively. Operative morbidity in the different groups was similar with regard to duration of ventilation, ICU and total hospital stay, postoperative septicaemia and stroke (Table 3). Severely obese patients had slightly less drainage at the 24th hour (520 mL vs 540 mL; $P = 0.04$) and a non-significant trend towards less blood transfusion (no packs of red blood cells versus one pack of red blood cells; $P = 0.08$). In the whole cohort, the

Table 1 Patient demographics and risk factors.

Variables	Sample, ($n = 3564$)	BMI 20—35 kg/m^2, ($n = 3282$)	BMI ≥ 35 kg/m^2, ($n = 282$)	*P*
Age (years)	67.3 ± 10.6	67.8 ± 10.7	62.5 ± 9.3	0.0001
Men	2542 (71.9)	2289 (70.3)	253 (89.7)	0.0001
LVEF (%)	56.4 ± 13.3	56.5 ± 13.4	54.2 ± 11.7	0.004
Dyspnoea, NYHA class				0.03
I	948 (29.1)	892 (29.7)	56 (21.6)	
II	1421 (43.6)	1292 (43.1)	129 (49.8)	
III	777 (23.9)	710 (23.7)	67 (25.9)	
IV	112 (3.4)	105 (3.5)	7 (2.7)	
Diabetes mellitus	1229 (34.7)	1080 (33.1)	149 (53.4)	0.0001
COPD	539 (15.1)	478 (14.6)	61 (21.6)	0.002
Preoperative stroke	268 (7.7)	244 (7.6)	24 (8.9)	0.44
Hypertension	2518 (71.7)	2294 (71.0)	224 (80.0)	0.001
Preoperative MI	820 (25.3)	741 (24.8)	79 (30.9)	0.03
Warfarin take	289 (11.8)	261 (11.7)	28 (13.6)	0.41
Clopidogrel take	622 (25.4)	562 (25.1)	60 (29.0)	0.22
Preoperative renal failure	466 (13.4)	426 (13.3)	40 (14.8)	0.48
Preoperative dialysis	19 (0.6)	18 (0.6)	1 (0.4)	1.00
PAD	742 (21.6)	673 (21.3)	69 (25.5)	0.11

Data are mean ± standard deviation or number (%). BMI: body mass index; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction; MI: myocardial infarction; NYHA: New York Heart Association; PAD: peripheral artery disease.

overall rates of mediastinitis, wound infection and 90-day mortality were 0.7% ($n = 24$), 2.7% ($n = 93$) and 4.0% ($n = 141$), respectively. Six (25%) of the patients with mediastinitis (four in group I and two in the severely obese group) died in the postoperative period; the others were successfully discharged.

As stated in the Methods section, we observed a significant interaction between the variables of severe obesity and diabetes for the hazard of mediastinitis, wound infection and death (data not shown); hence, analyses were done separately for non-diabetic and diabetic patients.

In non-diabetic patients, there were eight (0.4%) cases of mediastinitis in non-severely obese patients and no (0%) cases in severely obese patients. On the other hand, in diabetic patients, there were 10 (0.9%) cases of mediastinitis in non-severely obese patients and six (4.2%) cases in severely obese patients ($P = 0.002$). These findings were confirmed in the multivariable analysis, where severe obesity alone did not affect the rate of postoperative mediastinitis (HR non-estimable, as all severely obese subjects were censored) while the interaction between severe obesity and diabetes mellitus strongly increased this rate (HR: 4.386; $P = 0.004$).

Regarding wound healing, in non-diabetic patients, wound infections occurred in 37 (1.7%) patients in the non-severely obese group and in seven (5.4%) patients in the severely obese group ($P = 0.003$). In diabetic patients, wound infections were observed in 43 (4.1%) patients in the

Table 2 Preoperative characteristics of patients.

Variables	Sample, ($n = 3564$)	BMI 20—35 kg/m^2, ($n = 3282$)	BMI ≥ 35 kg/m^2, ($n = 282$)	*P*
Cross-clamp time (minutes)	66 (49—93)	66 (49—93)	65 (49—93)	0.34
CPB time (minutes)	84 (63—114)	84 (63—114)	84 (63—116)	0.22
Redo surgery	92 (2.6)	84 (2.6)	8 (2.8)	0.78
CABG	2075 (58.2)	1895 (57.7)	180 (63.8)	0.047
Distal anastomoses (*n*)	2 (0—3)	2 (0—3)	2 (0—3)	0.41
Number of ITAs				0.08
0	60 (2.5)	59 (2.7)	1 (0.5)	
1	1011 (42.0)	934 (42.3)	77 (38.9)	
2	1335 (55.5)	1215 (55.0)	120 (60.6)	
Off-pump CABG	475 (13.3)	436 (13.3)	39 (13.8)	0.80
Valvular surgery	988 (27.7)	923 (28.1)	65 (23.1)	0.07
Valve + CABG	346 (9.7)	325 (9.9)	21 (7.5)	0.18

Data are median (interquartile range) or number (%). BMI: body mass index; CABG: coronary artery bypass graft; ITA: internal thoracic artery.

Table 3 Postoperative outcomes of patients.

Variables	Sample, ($n=3564$)	BMI 20–35 kg/m^2, ($n=3282$)	BMI ≥ 35 kg/m^2, ($n=282$)	P
Duration of ventilation (hours)	6 (4–8)	6 (4–8)	5 (3–8)	0.21
ICU stay (days)	1 (1–2)	1 (1–2)	1 (1–2)	0.91
Hospital stay (days)	8 (7–9)	8 (7–9)	8 (7–9)	0.12
Amount of 24th-hour drainage (mL)	540 (380–780)	540 (380–780)	520 (380–700)	0.04
Transfused PRBCs (n)	0 (0–1)	0 (0–1)	0 (0–0)	0.08
Pulmonary infection	440 (12.4)	395 (12.0)	45 (16.0)	0.06
Urinary tract infection	77 (2.2)	74 (2.3)	3 (1.1)	0.19
Septicaemia	29 (0.8)	27 (0.8)	2 (0.7)	1.00
Postoperative stroke	50 (1.4)	45 (1.4)	5 (1.8)	0.59
Atrial fibrillation	757 (21.2)	691 (21.1)	66 (23.4)	0.35

Data are median (interquartile range) or number (%). BMI: body mass index; ICU: intensive care unit; PRBC: pack of red blood cells.

Table 4 Predictive value of severe obesity.

	Non-diabetic patients	Diabetic patients
Mediastinitis	NS	HR 4.39 ($p=0.004$)
Wound infection	HR 6.90 ($p=0.0001$)	NS
Mortality	NS	NS

HR: hazard ratio; NS: not significant.

first group and in six (4.2%) patients in the second group ($P=0.95$). Multivariable analysis confirmed that severe obesity alone affected the rate of wound infections negatively (HR: 6.90; $P=0.0001$) (Table 4).

Finally, concerning postoperative mortality, severe obesity was not related to an increased postoperative death rate. In non-diabetic patients, 81 (3.7%) deaths occurred in the non-severely obese group and three (2.3%) in the severely obese group ($P=0.41$). In diabetic patients, we observed 45 (4.2%) deaths in group I and 11 (7.5%) deaths in group II ($P=0.08$). These data were confirmed in the multivariable analysis (HR: 1.21, $P=0.75$ in non-diabetic patients; HR: 0.39, $P=0.35$ in diabetic patients), where only the interaction between severe obesity and preoperative renal failure was strongly related to operative mortality (HR: 11.17; $P=0.03$).

Discussion

Severely obese patients represent an increasing yet minor subgroup of obese patients. As data specifically evaluating these patients are rare, we decided to study this subgroup further.

In underweight patients, operative mortality after cardiac surgery, for both valvular surgery and CABG, has been found to increase significantly [3,7,8]. On the other hand, obese patients, paradoxically, had no increased mortality risk for similar surgical procedures [9]. Engelman et al. [2] proposed some explanations for this phenomenon. First, patients with a low BMI might have greater haemodilution after CPB, thus resulting in greater transfusion requirements. Second, these patients have less nutritional reserve, which might not allow them to handle postoperative complications optimally. Thus, these morbidities put together might be responsible for the increased operative mortality. On the other hand, Vaduganathan et al. [6] first provided data by analysing obese subgroups in their cohort of obese patients. The authors concluded that obese patients (without difference between obese subgroups) had greater survival after valve surgery than normal-weight patients, thereby fuelling the notion of the 'obesity paradox' [5]. Benedetto et al. [9] stated that one explanation for the 'obesity paradox' phenomenon might be that obese patients reported on in the literature [10,11] have better survival because of their lower risk profile, particularly their younger age. So obese patients may have better short- and medium-term survival simply due to their age. In our study, severely obese patients were significantly younger than obese or normal-weight patients. The younger age in the severely obese group might be explained in our cohort by a patient selection bias, with surgeons choosing young obese patients in order not to burden their comorbidities before surgery. However, isolated severe obesity in our study was not related to operative mortality. On the other hand, the interaction between preoperative renal failure and severe obesity had a strong negative influence on postoperative survival.

Previous studies have shown an association between obesity and postoperative morbidity, such as wound infection [4], renal failure [2] or occurrence of atrial fibrillation [12]. Wigfield et al. [13] authored a report in a retrospective series of 1920 patients, and found that severely and morbidly obese patients have significantly increased complications with respect to length of stay, rate of postoperative renal failure and prolonged mechanical ventilation compared with normal-weight patients. Our results differ from theirs: for our severely obese patients, length of stay and rate of renal failure were not increased. These contradictory data might be explained by the larger number in our cohort

(3654 patients in 8 years), thus giving us a greater statistical power. In our study, we were only able to show a relationship between isolated severe obesity and superficial wound infection. However, isolated severe obesity did not influence the rate of mediastinitis. The interaction between diabetes mellitus and severe obesity was a strong factor that significantly influenced this postoperative issue. These findings might help clinicians to identify a patient's complication risk profile and to be prepared for extra-careful monitoring of surgical wound healing in this group (Table 4).

With respect to transfusion, we observed that severely obese patients experienced a lower rate of postoperative bleeding, but that this was not reflected in transfused packs of red blood cells. At first, these results appear counterintuitive, yet they are consistent with previous reports [2,4,14]. A possible explanation might be the decreased haemodilution of obese patients compared with normal-weight patients, following the CPB priming.

Finally, some authors have advocated hypoalbuminaemia [2] as an independent predictor of increased morbidity and mortality after cardiac operations. Records of serum albumin concentrations were unavailable to us; however, this issue should be addressed in future studies. As albumin concentration is related to nutritional status, hypoalbuminaemia occurs more frequently in patients with malnutrition and is probably related to an increased rate of postoperative complications.

Study limitations

Our study has some limitations due to the retrospective analysis. Although we attempted to control for confounding variables, it is probable that some biasing factors are lacking (e.g. serum albumin concentration, rate of insulin-dependent diabetes mellitus). This probably would have allowed us to better analyse the influence of nutritional status or preoperative control of diabetes (by mean of insulin or oral antidiabetics) on postoperative outcomes in normal-weight and severely obese patients.

Conclusion

The main finding of this study was that severely obese patients can have elective cardiac surgery, like patients in the general population, and that they have no operative mortality or morbidity increase aside from wound infection. This risk may be enhanced by diabetes mellitus and clinicians must pay particular attention to wound healing in patients accumulating multiple risk factors. Nevertheless, morbid obesity should not in itself be a contraindication to elective surgery.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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