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Pulmonary function after coronary artery bypass surgery

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Coronary artery bypass graft surgery (CABG) adversely affects pulmonary function tests (PFTs). Although several previous studies have addressed these changes, none has measured the forced vital capacity (FVC) on a daily basis. The purpose of the present study was to assess serial changes in the FVC following CABG and to identify factors that may influence these changes. The FVC was obtained pre- and daily postoperatively (1–10 days) in 120 patients. Fifty-one patients received saphenous vein grafts (SVG group) while 69 received at least one internal mammary artery graft in addition to SVG (IMA group). On the first postoperative day, the FVC decreased to 33% of the pre-operative value in the SVG group and to 29% in the IMA group. The spirometry gradually improved, but after 10 days, the FVC remained reduced (SVG, 70%; IMA, 60%). Although the decreases in FVC tended to be greater in the IMA group, there was no significant difference in the two groups ($P=0{\cdot}27$). The changes in FVC were not significantly related to age ($P=0{\cdot}48$), smoking history ($P=0{\cdot}65$), anesthesia ($P=0{\cdot}38$) or pump time (0·09). From this study, it is concluded that after CABG, there is a significant worsening of the pulmonary function. The nadir of FVC occurs immediately after surgery and improves gradually thereafter. However, on the tenth postoperative day, the FVC still remains more than 30% below pre-operative values. Since there is only a slight tendency for patients undergoing IMA grafting to have larger decreases in their pulmonary function, patients with ventilatory impairment should not be excluded from IMA grafting.

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Introduction

Impairment of pulmonary function is one of the most significant postoperative complications of coronary artery bypass graft surgery (CABG). There have been several previous reports on pulmonary function post CABG (1–3), but in none of them was the FVC evaluated on a daily basis postoperatively.

Internal mammary artery grafting (IMA) has been reported to have better long-term patency rates than saphenous vein grafting (SVG) (3). There is a trade-off when IMA grafts are used because the mediastinum and thoracic cavity are traumatised more with the IMA than with the SVG procedure. Indeed, some reports have found that IMA patients have worse pulmonary function than SVG patients in the post-operative period (1,4). However, the present authors have reported that there is no significant difference in the incidence of atelectasis or pleural changes in the two different groups (5,6). Moreover, they have reported that on the second postoperative day, the changes in the PaO_2 are similar in both groups, but that the abnormalities in the blood gases tend to resolve more slowly in the IMA group (7).

The purposes of this study were primarily to document the serial changes in forced vital capacity (FVC) after coronary artery bypass grafting, and secondarily to identify factors that may influence these changes.

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Methods

Consecutive male patients undergoing elective CABG were selected prospectively at the Instituto do

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Coracao (INCOR) of the Faculty of Medicine of the University of Sao Paulo, Brazil. This same group of patients has been the subject of three previous papers (5–7). To be included in this protocol, the patients had to either undergo only SVG grafts with no excessive manipulation of the pleura (SVG group), or alternatively to have at least one IMA graft with pleurotomy in addition to the SVG grafts (IMA group). The study had prior approval by the INCOR committee on protection of human subjects.

Postoperatively, a small tube was used in all patients to drain the mediastinum. Chest tubes for draining the pleural space were used in all the patients of the IMA group. On the first postoperative day, the patients were in the Intensive Care Unit and all the IMA patients still had the intercostal chest tube in place. On the second day, the tube had been removed from all but four of the IMA patients. The patients were discharged from the hospital on an average of 10·3 ± 2·7 days after surgery.

All subjects pre-operatively and on the sixth post-operative day underwent pulmonary function testing (PFTs) in a standing position with a pulmonary function analyser (HP 47402A). Before and daily after the surgery, the patients were submitted to measurements of FVC with a portable monitor (Bourns LS-75). The tests were done in the supine position on the first and second postoperative days and in standing and supine positions from the third to the tenth postoperative day. Two FVC manoeuvres were performed with the patients supine and two FVC manoeuvres were performed with the patients standing. The highest value in each position was used for data analysis. The observed values were compared with the predicted values of Knudson *et al.* (8).

Before performing the tests each day, the patients were asked about any major discomfort. If present, the test was postponed to the next day. Starting on the sixth postoperative day, a few patients were discharged from the hospital. These factors explain why the number of patients at each observation period is not the same.

STATISTICAL ANALYSIS

Data are expressed as the mean ± standard deviation. The effects of age, smoking habit, IMA harvesting and time of anesthesia or cardiopulmonary bypass on the postoperative changes were determined by multivariate regression analysis with the values of the FVC expressed as a percentage of the pre-operative value as the dependent variables. To ascertain whether there were statistically significant differences between the SVG and IMA groups, the percent decrease in the FVC was compared using one-way ANOVA with repeated measures. When the test of normality failed, the Friedman repeated measures analysis of variance on ranks was performed. The differences between standing and supine positions and between the measurements of the FVC with the HP analyser or with the portable monitor, were compared with the paired *t*-test. Probability values less than 0·05 were considered significant.

TABLE 1. Subjects and surgery characteristics

	SVG	IMA
Age (years)	57·7 ± 7·5	56·8 ± 6·6
Weight (kg)	68·3 ± 9·6	67·5 ± 10·2
Smoke (pack/years)	26·0 ± 29·6	28·5 ± 30·4
Preoperative PFTs		
FVC (% pred.)	92·9 ± 17·6	96·3 ± 15·3
FEV_1 (% pred.)	97·9 ± 18·7	100·6 ± 16·8
Times		
Anesthesia (min)	351 ± 71	363 ± 79
Pump (min)	114 ± 34	125 ± 36

SVG, saphenous vein grafts; IMA, internal mammary artery graft; PFT, pulmonary function test; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s.

Results

After surgery, 120 patients were maintained in this protocol; 51 had undergone only saphenous vein grafts with no excessive manipulation of the pleura (SVG group) and 69 patients had received at least one internal mammary artery graft with pleurotomy in addition to the SVG (IMA group). Eight patients were dropped from the protocol after surgery. Two of these were dropped because they developed bleeding and required additional surgery. Six patients were dropped because they were too confused post-operatively to perform the pulmonary function testing. These latter six patients appeared to have a cerebrovascular accident in the immediate post-operative period, but had no long-term neurological deficits.

The characteristics of both groups were very comparable pre-operatively (Table 1). The means of age and weight were slightly higher in the SVG group, but the differences did not achieve statistical significance ($P=0·38$ for age and 0·42 for weight). Despite significant smoking histories, the mean FVC and FEV_1 were more than 90% in both groups. The anesthesia and extracorporeal circulation times were slightly

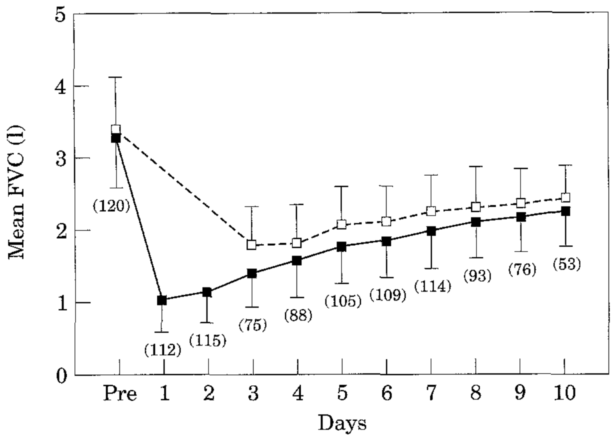

FIG. 1. The mean forced vital capacity (FVC) pre-operatively and for the first 10 postoperative days in the supine (■) and standing (□) positions. The bars represent 1 standard deviation and the numbers in parentheses indicate how many patients were tested each day. The pre-operative FVC was significantly higher than any of the postoperative values. The mean values on Days 7 and 10 were significantly greater than those on the first four postoperative days. On each day, the mean supine FVC was significantly lower than the mean standing FVC.

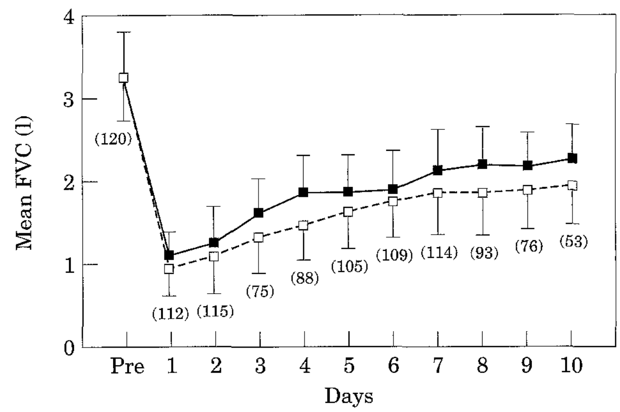

FIG. 2. The mean forced vital capacity (FVC) pre-operatively and for the first 10 days postoperatively in the 51 patients undergoing saphenous vein grafts (SVG) (■) and the 69 patients undergoing internal mammary artery (IMA) grafts (□). Although the decreases in the FVC tended to be higher in the IMA group, the differences did not reach statistical significance (P>0·05).

greater in the IMA group (363 ± 79 and 125 ± 36 min) than in the SVG group (351 ± 71 and 114 ± 34 min), but the differences observed were not statistically significant (P=0·54 for anesthesia and 0·39 for extracorporeal circulation time).

On the day following surgery, the bedside supine FVC was markedly reduced with mean value of 31% of the pre-operative value. The decrement observed in the FVC was not significantly correlated with age (P=0·49), smoking history (P=0·65), anesthesia (P=0·38) or pump time (P=0·09). The mean value for the FVC on this first postoperative day was the lowest obtained and the values show progressive improvement over the next 10 days (Fig. 1). Nevertheless, the mean FVC was only 62·5% of the pre- operative value on the sixth postoperative day and 70% of the pre-operative value on the tenth postoperative day. As anticipated, the nadir for the FVC in the standing position was observed on the third day which was the first time it was measured in this position. The standing FVC improved comparably with the supine FVC during the period of observation (Fig. 1). At all observation times (excluding the pre-operative evaluation), the standing FVC was significantly higher (P<0·01 to 0·04) than the supine FVC.

There were no statistically significant differences in the decreases in the FVC in the SVG group as compared to the IMA group, although the mean decreases in FVC were slightly less in the SVG group. On the first postoperative day, the FVC in supine position decreased to an average of 33% of the pre-operative value in the SVG group and to 29% in the IMA group (Fig. 2) (P=0·11). The decreases observed throughout the postoperative period were slightly greater in the IMA group than in the SVG group, but none of these differences achieved statistical significance. On the tenth postoperative day, the FVC remained around 70% of the pre-operative value in the SVG group and 63% in the IMA group. The mean improvement in the FVC between the first post-operative day and the 7th postoperative day or the last day of observation did not differ significantly in the two different groups.

No statistically significant differences (P>0·05) were observed between the values of the FVC obtained with the HP analyser or with the portable monitor (Bourns) in the pre-operative period (P=0·31), or on the sixth postoperative day (P=0·16) in the standing position (Table 2).

Discussion

There were substantial changes in vital capacity following myocardial revascularisation. On the first postoperative day, the observed decrement was around 70% of the pre-operative value. Thereafter, there was a gradual improvement over the next 10 days. Ten days after surgery, when in general the patients are able to be discharged from the hospital,

TABLE 2. Spirometric results (standing position)

Pulmonary function analyser	HP 47402A	Bourns
FVC (% pred.)		
Pre-operative	95·2 ± 16·5	93·1 ± 15·8
Sixth postoperative day	64·9 ± 14·7	62·5 ± 11·6
FEV_1 (% pred.)		
Pre-operative	99·5 ± 18·3	
Sixth postoperative day	67·8 ± 15·4	
$(FEV_1/FVC) \times 100$		
Pre-operative	82·4 ± 9·6	
Sixth postoperative day	80·8 ± 9·7	

FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

the FVC had increased but still remained 30% lower than the pre-operative value. Since the decrement in the FEV_1 on the sixth postoperative day was actually slightly less than that observed in the FVC (Table 2), a restrictive impairment was present.

One possible criticism of the present study is that the Bourns LS-75 portable monitor was used to measure the vital capacity in most instances. The authors believe that this criticism is unjustified since the results of the pulmonary function testing performed pre-operatively and on the sixth postoperative day with the Bourns portable monitor and the HP 47402A automated pulmonary function analyser were nearly identical.

The degree to which the FVC was reduced in the present study is comparable to that reported by other authors. Jenkins *et al.* (1) reported that the mean FVC was reduced to 36% of the pre-operative value on the second postoperative day in 77 patients receiving IMA grafts and to 45% of the pre-operative values in 33 patients receiving only SVGs. Van Belle *et al.* (9) studied pulmonary functions before and 1 week after coronary artery bypass grafting. They reported that 7 days postoperatively, the FVC had decreased to 33% of the pre-operative value, which is very similar to the decrease in the present paper (9).

The postoperative changes in FVC were measured in both the standing and the supine positions. In normal individuals, the FVC is approximately 7% lower in the supine position than in the standing position (11). The results of the present study are compatible with those of Berrizbeitia *et al.* who reported that following coronary artery bypass surgery, the reduction in the FVC is more in the supine than in the standing position (12) The FVC decrement observed in the present study on the third postoperative day in the supine position was 1·89 l compared to a decrement of 1·49 l in the standing position. This result suggests that in the immediate postoperative period, the restrictive influence of abdominal viscera is more pronounced in the supine position. The explanation for this is not definitely known but it is likely that it is explained at least in part by diaphragmatic dysfunction resulting from phrenic nerve injury (13). DeVita *et al.* (13) studied 92 patients after coronary artery bypass surgery and reported that 24 of the 42 patients who had abnormal diaphragmatic motion by ultrasound postoperatively had diaphragmatic dysfunction as evidenced by phrenic nerve conduction studies and diaphragmatic electromyography.

The postoperative decrease in FVC was similar in SVG or IMA groups. Pleurotomy (associated with IMA grafting) was not found to lead to larger changes in the FVC in the days immediately post-surgery. It has been suggested that the pleura should not be opened during dissection of the IMA graft because pleurotomy is associated with a high incidence of postoperative pulmonary complications (2,14). Some authors have reported larger decreases in the FVC with IMA grafting (1,12), while others have reported comparable decreases in PFTs with both procedures (14). The present study gives no support to the contention that the decreases in FVC are significantly greater in the IMA group.

Throughout the postoperative period, the patients who had the IMA surgery tended to have a slightly lower FVC. One might question whether this protocol had sufficient power to detect clinically significant differences in the changes in the FVC. If one assumes that a difference of 400 ml in the FVC decrement is clinically significant, and if one assumes that the standard deviation of the decrement is 0·72 l, the power of the present analysis to detect this difference was 0·85. However, if one assumes that a difference of 200 ml in the FVC decrement is clinically significant, then the power of the present analysis was only 0·32. The observed differences were in the range of 100–200 ml so these differences would not have been expected to be statistically significant.

The decrease observed in FVC on the first postoperative day in both groups was impressive. However, it was only slightly greater in the IMA group (70·9%) than in the SVG group (66·7%). Analysis of the data shows that the decrement during the entire postoperative period tended to be greater ($\sim$7%) in the IMA group than that in the SVG group. The decrement observed on the tenth postoperative day was 30·5% in the SVG group and 39·9% in the IMA group. the improvement observed between the second and the tenth postoperative day was similar (20%) in both groups ($P>0{\cdot}05$). This suggests that the additional trauma associated with IMA grafting (pleurotomy and placing of pleural drains) does not result in a longer recovery time in the IMA group than in the SVG group. The authors' impression is the decrement in FVC is related to sternotomy, and that the increased morbidity represented by atelectasis or pleural changes is responsible for worsening of the pulmonary function (6,15).

In conclusion, this study demonstrates that following CABG, there is a marked decrease in the FVC. The nadir for the FVC occurs immediately after surgery and improves gradually thereafter. However, on the tenth postoperative day, the FVC still remains below pre-operative values. The postoperative changes in FVC were observed either in standing or supine positions. In the supine position, the FVC was more reduced on the third postoperative day, presumably reflecting the contribution of the abdominal viscera displacement and some degree of phrenic nerve dysfunction. The significant decrease in FVC was not dependent on intra-operative variables. There tended to be a slightly greater decrease in the FVC after IMA grafting than after SVG, but the differences did not appear to be significant, either statistically or clinically. Therefore, in view of the more favourable patency rates of IMA grafts, patients with marginal ventilatory reserve undergoing CABG should not be excluded from IMA grafting, whenever indicated and technically feasible.

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