

# GENERAL THORACIC SURGERY

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## PERIOPERATIVE COMPLICATIONS AFTER LIVING DONOR LOBECTOMY

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**Objective:** Clinical lung transplantation has been limited by availability of suitable cadaveric donor lungs. Living donor lobectomy provides right and left lower lobes from a pair of living donors for each recipient. We reviewed our experience with living donor lobectomy from July 1994 to February 2000.

**Methods:** Sixty-two donor lobectomies were performed. The hospital and outpatient records of these 62 donors were retrospectively analyzed to examine the incidence of perioperative complications.

**Results:** Twenty-four (38.7%) of 62 donors had no perioperative complications and had a median length of hospital stay of 5.0 days. Thirty-eight (61.3%) of 62 donors had postoperative complications. Twelve major complications occurred in 10 patients and included pleural effusions necessitating drainage (n = 4), bronchial stump fistulas (n = 3), bilobectomy (n = 1), hemorrhage necessitating red cell transfusion (n = 1), phrenic nerve injury (n = 1), atrial flutter ultimately necessitating electrophysiologic ablation (n = 1), and bronchial stricture necessitating dilatation (n = 1). These 38 donors had 55 minor complications including persistent air leaks (n = 9), pericarditis (n = 9), pneumonia (n = 8), arrhythmia (n = 7), transient hypotension necessitating fluid resuscitation (n = 4), atelectasis (n = 3), ileus (n = 3), subcutaneous emphysema (n = 3), urinary tract infections (n = 2), loculated pleural effusions (n = 2), transfusion (n = 2), *Clostridium difficile* colitis (n = 1), puncture of a saline breast implant (n = 1), and severe contact dermatitis secondary to adhesive tape (n = 1). There were no postoperative deaths and only 1 donor required surgical re-exploration.

**Conclusions:** Living donor lobectomy can be performed with low mortality and remains an important alternative for potential recipients unable to wait for cadaveric lung allografts. However, morbidity is high and must be considered when potential living donors are being counseled. (*J Thorac Cardiovasc Surg* 2000;120:909-15)

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The current availability of suitable cadaveric donor lungs has not been able to meet the increasing need for these organs in the management of patients with end-stage pulmonary disease requiring lung transplantation. In 1998 alone, 498 patients died while awaiting a cadaveric lung transplant.<sup>1</sup> The majority of these deaths occurred in patients with inflammatory lung disease such as cystic fibrosis and pulmonary fibrosis. In an effort to meet this need for donor lungs, the technique of living donor lobectomy has been developed.<sup>2,3</sup> Although the results of living donor transplantation have been previously reported with respect to recipient outcomes, an examination of early postop-

**Table I.** Criteria for living lobar lung donation

Donor criteria
Age $\leq$ 60 y
No significant medical history or active medical problems
No recent viral infection
No abnormalities on the electrocardiogram
No abnormalities on the chest radiograph
No significant surgery on the donor side
Pulmonary function, including spirometry, lung volumes, diffusion capacity, and arterial blood gases, within normal limits
Forced expiratory volume $\geq$ 85% of predicted
Arterial oxygen tension $\geq$ 80 mm Hg
Exclusion criteria
ABO incompatibility
Psychological instability
Seropositivity for HIV, hepatitis B, or hepatitis D
Inability to meet the psychological criteria defined above
Active tobacco smoking, or a $>$ 20 pack-year history
Single parent responsible for a young child

HIV, Human immunodeficiency virus.

erative outcomes in donors has not been specifically performed.<sup>4-13</sup> The purpose of this study was to examine the incidence of perioperative complications after living donor lobectomy.

## Methods

From July 1994 through February 2000, a total of 62 living donor lobectomies were performed to provide a pair of donor lobes for pediatric recipients with end-stage lung disease. In each instance, two separate operating teams at Barnes-Jewish Hospital performed simultaneous living donor lobectomies and the recipient operation was performed at St Louis Children's Hospital. The timing of each donor operation was coordinated closely with the surgeons performing the recipient procedure to minimize the ischemic time for each donor lobe. The hospital and outpatient records of 62 consecutive lung donors were retrospectively examined. All perioperative and postoperative complications were identified and analyzed.

**Indications for transplantation.** Thirty-one pediatric patients with end-stage lung disease underwent bilateral lobar transplantation. The policy of our pediatric lung transplant colleagues has been to limit this procedure to patients who are in unstable condition or who are unlikely to survive the long wait for cadaveric lungs. The original indications for transplantation included cystic fibrosis ( $n = 26$ ), idiopathic bronchiolitis obliterans ( $n = 2$ ), pulmonary hypertension ( $n = 2$ ), and pulmonary arteriovenous malformation ( $n = 1$ ). Patients with pulmonary hypertension secondary to cardiac defects or pulmonary venous occlusive disease were not specifically excluded. However, no patients with these diagnoses underwent living lobar transplantation in this series.

All recipients were dependent on supplemental oxygen at the time of transplantation and 16 patients were hospitalized. Fourteen of these 16 patients were dependent on a ventilator. Ten patients with the original diagnoses of cystic fibrosis

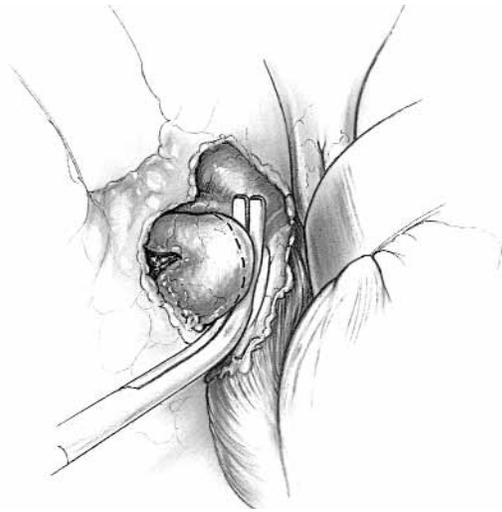
( $n = 8$ ) and pulmonary hypertension ( $n = 2$ ) had undergone transplantation earlier. The indication for retransplantation was the development of bronchiolitis obliterans after cadaveric lung transplantation in 8 patients and primary graft failure in 2 patients.

**Donor selection.** All potential donors were screened, evaluated, and concurrently monitored by the adult pulmonary medicine service. An extensive discussion describing the donor lobectomy procedure, the potential perioperative risks, and the uncertain outcome for the recipient was conducted with each of the potential donors. Potential donors who wished to proceed then underwent a complete history and physical examination and a formal psychological evaluation.<sup>14</sup> Routine laboratory testing was performed, including a complete blood count, metabolic profile, prothrombin and partial thromboplastin times, and serologic testing for relevant infections. All potential donors had a chest radiograph, pulmonary function tests, a ventilation-perfusion lung scan, an electrocardiogram, and when indicated, a cardiac stress test (Table I).

Potential donors with no significant medical or psychological contraindications were considered suitable donor candidates and were referred to the thoracic surgeons for further evaluation. The entire donor evaluation was completely confidential and the reasons for donor exclusion were not disclosed to other family members or the physicians caring for the potential recipient. Throughout the entire donor evaluation process, multiple opportunities to question, reconsider, or withdraw as a donor were provided to the potential donors. The decision concerning which lobe would be resected from each donor was based on an optimal size match between the available donor and recipient.

## Operative technique

**Donor right lower lobectomy.** For living donor lower lobectomies, we used techniques similar to those previously described.<sup>3</sup> Lumbar epidural catheters were placed routinely. Latissimus dorsi muscle-sparing thoracotomy incisions were used whenever possible. In brief, the donor right lower lobectomy was performed by first mobilizing the inferior pulmonary ligament to the level of the inferior pulmonary vein. The posterior hilum was then opened to the level of the bronchus intermedius. The pericardium was opened circumferentially at the level of the inferior pulmonary vein, exposing the pulmonary vein-left atrial junction. The pulmonary artery was then dissected in the major fissure identifying the superior segmental branch and the branches to the middle lobe. So that additional length on the donor pulmonary artery could be obtained, a small distal branch to the middle lobe was often divided with preservation of the main arterial branch to the middle lobe. If incomplete, the oblique fissure was divided by means of multiple fires of the GIA stapling device (Auto Suture Company, Division of United States Surgical Corporation, Norwalk, Conn). Intravenous alprostadil (prostaglandin E<sub>1</sub>) was administered to reduce the systemic systolic pressure by 10 mm Hg. The patient was then given 5000 units of intravenous heparin. After the heparin had circulated for 3 minutes, a vascular clamp was placed on the lower lobe pulmonary artery above the level of the superior segmental branch. A second clamp was placed

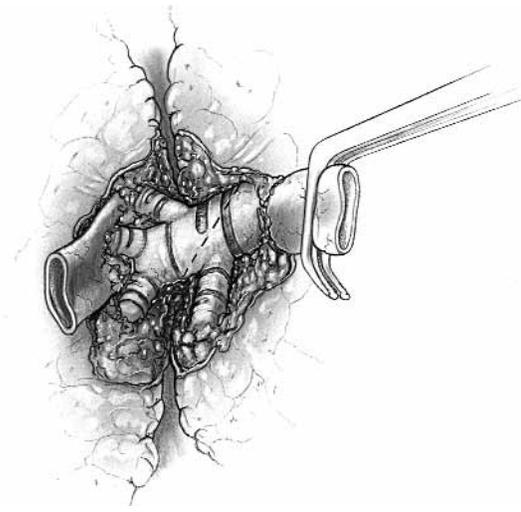


**Fig 1.** The pericardium is opened at the level of the inferior pulmonary vein, exposing the inferior pulmonary vein–left atrial junction. A vascular clamp is placed on the left atrium. In many cases there are actually two branches of the inferior pulmonary vein that meet at the atrial junction. In these situations, it is important to divide the vein at the pulmonary vein–atrial junction (*dashed line*) to have a single orifice for reanastomosis of the inferior pulmonary vein in the recipient.

on the left atrium to provide maximal length on the inferior pulmonary vein (Fig 1). After division of these vessels, attention was directed to the lower lobe bronchus. The superior segmental bronchus and the middle lobe bronchus were identified, and an oblique bronchotomy was performed to maintain adequate length for closure of the donor bronchus and maximal length for anastomosis in the recipient (Fig 2).

The donor lobe was then removed to a separate table in the operating room in preparation for transplantation. While the lobe was immersed in iced saline solution, the lower lobe bronchus was intubated with a size 4 uncuffed endotracheal tube. The lower lobe was then gently reinflated with 100% oxygen. After re-expansion, a bulldog clamp was used to seal the bronchus. The lobe was then flushed with 1.5 L of modified Euro-Collins solution ( $\text{MgSO}_4$ , 4 mEq; glucose, 3 g/100 mL) antegradely via the pulmonary artery and retrogradely via the pulmonary vein. The lobe was then packed on ice and transported for transplantation into the recipient.

The donor pulmonary arterial stump was oversewn with a 5-0 polypropylene continuous suture, and the left atrial stump was oversewn with a 4-0 polypropylene continuous suture. The oblique bronchotomy was then closed with 4-0 Vicryl interrupted sutures (Ethicon, Inc, Somerville, NJ). If the bronchial orifice of the right middle lobe was narrowed by this closure, the right middle lobe was reimplanted end to end to the bronchus intermedius. Each bronchial closure was then covered with a pleural flap. The thoracotomy was closed in a standard manner after placement of 2 chest tubes. The patient was extubated in the operating room before transfer to the postanesthesia care unit.

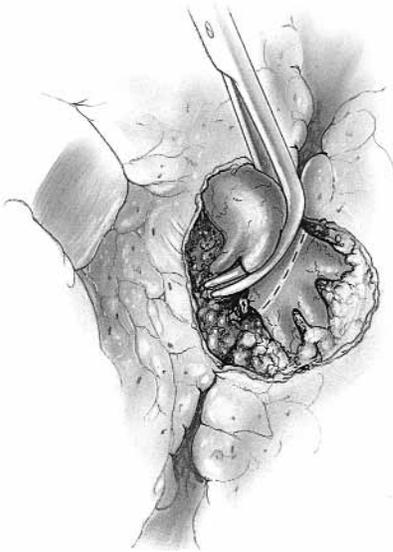


**Fig 2.** The superior segmental bronchus and the middle lobe bronchus are identified. The *dashed line* denotes the site of division of the right lower lobe bronchus. An oblique bronchotomy is performed to maintain adequate length for closure on the donor bronchus and maximal length for anastomosis in the recipient.

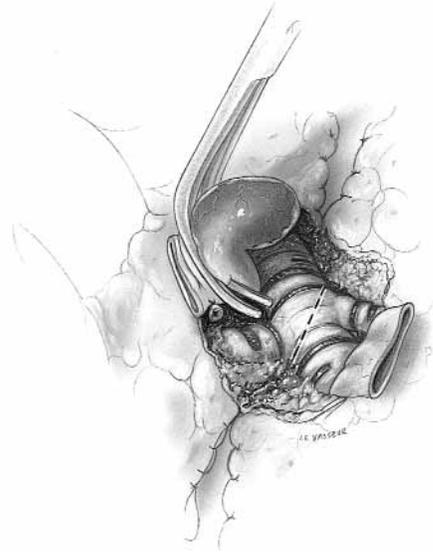
*Donor left lower lobectomy.* Donor left lower lobectomy was performed in a similar manner to the donor right lower lobectomy. The inferior lingular artery branch was divided routinely to obtain additional length of pulmonary artery on the lower lobe side. Because we observed excellent back bleeding from this branch in our early experience, we made no attempt at reimplantation. Compared with donor right lower lobectomy, it was often easier to obtain additional donor bronchial length during division of the left lower bronchus without encroachment on the left upper lobe bronchus (Figs 3 and 4).

## Results

**Recipient results.** Thirty-one patients underwent bilateral lobar transplantation. Twenty-two (71.0%) of 31 recipients recovered and were discharged from the hospital. Nine (29.0%) of 31 patients died during the early postoperative period. The cause of death was primary graft failure in 7 patients and sepsis in 2 patients. There were 5 additional deaths in this series. Three deaths occurred within the first year after transplantation. The cause of death in these 3 patients was sepsis ( $n = 1$ ), cerebral hemorrhage ( $n = 1$ ), and sudden cardiac death ( $n = 1$ ). The overall 1-year actuarial survival was 63.7%. Two additional patients died 3.5 years after transplant. One died of a hepatic leiomyosarcoma and 1 died of respiratory syncytial virus pneumonia.



**Fig 3.** The left pulmonary artery is dissected in the fissure and the arterial branches to the lingula and superior segment of the left lower lobe are identified. Routine division of the inferior lingular branch without an attempt at reimplantation is performed to obtain additional length on the donor pulmonary artery. A vascular clamp is placed on the pulmonary artery just inferior to the takeoff of the lingular artery. The *dashed line* denotes the site of division of the left lower lobe pulmonary artery.



**Fig 4.** The superior segmental bronchus and the left upper lobe bronchus are identified. The pulmonary artery to the left lower lobe is reflected with a pair of forceps. The *dashed line* denotes the site of division of the left lower lobe bronchus. An oblique bronchotomy is performed to maintain adequate length for closure on the donor bronchus and maximal length for anastomosis in the recipient.

**Table II. Major complications**

Complication	No.
Pleural effusions necessitating drainage	4
Bronchial stump fistulas	3
Hemorrhage necessitating transfusion	1
Permanent phrenic nerve injury	1
Atrial flutter necessitating electrophysiologic ablation	1
Bilobectomy	1
Bronchial stricture necessitating dilatation	1

**Donor complications.** Twenty-four (38.7%) of 62 donors had no complications. The median length of stay for this group of patients was 5.0 days. Thirty-eight (61.3%) of 62 donors did have postoperative complications. There was no significant difference in the overall complication rate between donor right lower lobectomy and donor left lower lobectomy (20/31 vs 18/31,  $P = .6$ ). There were no postoperative deaths in this series.

Twelve major complications occurred in 10 donors (Table II). Fifty-five minor complications occurred in 38 donors and resulted in a prolonged initial hospi-

**Table III. Minor complications**

Complication	No.
Persistent air leaks	9
Pericarditis	9
Pneumonia	8
Arrhythmia	7
Hypotension	4
Atelectasis	3
Ileus	3
Subcutaneous emphysema	3
Urinary tract infection	2
Loculated pleural effusion	2
Transfusion	2
<i>Clostridium difficile</i> colitis	1
Breast implant rupture	1
Severe contact dermatitis	1

talization or the need for subsequent hospital readmission (Table III). The complications can be categorized as follows: (1) perioperative hemorrhage, (2) airway complications, (3) pleural effusions, (4) arrhythmias, (5) pneumonia and atelectasis, (6) pericarditis, (7) persistent air leaks, and (8) miscellaneous complications.

*Perioperative hemorrhage.* One donor had significant sanguineous chest tube drainage in the immediate postoperative period that responded to heparin reversal with protamine. However, this donor required packed cell transfusion for a hematocrit value of 24%. Two additional donors required packed cell transfusions for anemia associated with fatigue on exertion. Four other donors had hypotension that responded to volume resuscitation. However, in each case, the hypotension was transient and the donor did not require red blood cell transfusion.

*Airway complications.* Five donors had airway complications. Bronchial stump fistulas developed in 3 of them, 1 of whom required surgical re-exploration for a large air leak. One donor was readmitted with a large pneumothorax. After placement of the chest tube, a large air leak was noted. A small bronchial stump fistula responded to chest tube drainage and bronchoscopic treatment with fibrin glue. The other small bronchial stump fistula healed with conservative chest tube management.

One donor required removal of the right middle lobe after the bronchus to that lobe was inadvertently divided while the anterior portion of the major fissure was being completed with the linear stapling device. One donor had a bronchial stricture after left lower lobectomy and presented with unilateral wheezing 4 weeks after lobectomy. Bronchoscopic examination demonstrated a tapering of the distal left main stem bronchus at the level of the orifice to the left upper lobe. This stricture was dilated 6 weeks after the operation with symptomatic improvement.

*Pleural effusions.* Four donors had large pleural effusions that necessitated drainage. Each of these effusions responded to pigtail catheter drainage without the need for subsequent intervention. Two other donors with small loculated pleural effusions did not require catheter drainage.

*Arrhythmias.* One donor had intractable atrial flutter that was resistant to amiodarone and 2 separate attempts at cardioversion. The atrial flutter was ultimately controlled with electrophysiologic ablation of the conduction pathway, and this donor has had no further episodes of cardiac arrhythmia. Seven donors had atrial fibrillation necessitating antiarrhythmic medication. In 3 of them the arrhythmia did not immediately convert to sinus rhythm with therapy, and warfarin anticoagulation was necessary for 3 months. Once sinus rhythm was restored, these 3 donors did not require further treatment with antiarrhythmic medications.

*Pneumonia and atelectasis.* Eight donors had postoperative pneumonia that resolved with intravenous and

oral antibiotic treatment. One of these donors had an associated pleural effusion treated by catheter drainage. Cultures from the pleural fluid grew *Eikenella corrodens*. Three additional donors had persistent basilar atelectasis that prolonged their hospitalizations.

*Pericarditis.* Postoperative pericarditis was identified in 9 donors. Fever, pericardial rub, S-T segment elevation on the electrocardiogram, and an elevated white blood cell count were the presenting features. Two of these patients had associated small pleural effusions. Resolution of pericarditis and the pleural effusions occurred in each of these donors after treatment with indomethacin (INN: indometacin). Interestingly, pericarditis was observed only after donor left lower lobectomy (9/31 vs 0/31,  $P = .002$ ).

*Persistent air leaks.* The most common minor complication was an air leak that persisted for more than 7 days. Each of these leaks resolved spontaneously with continued chest tube drainage.

*Miscellaneous complications.* Donors had other minor complications including ileus secondary to narcotic analgesic administration, subcutaneous emphysema, urinary tract infections, *Clostridium difficile* colitis, intraoperative puncture of a saline breast implant with the needle of a fascial closure suture, and severe contact dermatitis secondary to adhesive tape (Table III).

## Discussion

Living donor lobar transplantation has been developed as an alternative to cadaveric lung transplantation in patients with end-stage lung disease. However, living donor lobectomy exposes 2 healthy individuals to the morbidity and potential mortality associated with a major pulmonary resection. Before the indications for living donor lung transplantation are expanded, a detailed analysis of the complications associated with this procedure is required.

Although we were able to closely analyze the perioperative course after donor lobectomy, long-term follow-up of donors after this operation has been more difficult. Many donors live far from our medical center and are reluctant to return for routine follow-up evaluations. This problem is exacerbated in cases in which the recipient dies, because we are unwilling to insist on routine examinations in a grieving parent or relative. As a result, postoperative pulmonary function tests (performed either at our institution or at a pulmonary function laboratory close to the donor's home) were available in only 24 of 62 donors. In this subset of donors, the mean preoperative forced expiratory volume in 1 second was  $104\% \pm 16\%$  of predicted (median 101%)

and fell to  $80\% \pm 16\%$  of predicted (median 83%) in the postoperative period. Although this decrease in forced expiratory volume in 1 second and forced vital capacity is similar to values previously reported,<sup>10</sup> it may not accurately reflect the postoperative pulmonary function of the entire group of donors.

In this retrospective analysis, 38 (61.3%) of 62 donors had postoperative complications. Although the majority of these complications were minor, 10 donors (16.1%) had 12 major complications that required subsequent intervention. Of these, 3 complications resulted in permanent loss of function (phrenic nerve paralysis, additional loss of the right middle lobe, and development of a bronchial stricture).

There are 3 technical differences between living donor lobectomy and standard lobectomy that likely explain the higher complication rate with the former procedure. First, the intrapericardial dissection of the inferior pulmonary vein results in a left atrial suture line with an increased risk for atrial arrhythmias and pericarditis. Second, an oblique bronchotomy is required to create a single bronchial orifice that includes the superior segmental bronchus and the bronchus to the basilar segments. This bronchotomy is then closed with interrupted adsorbable suture, sometimes under tension, which increases the risk for bronchial stump dehiscence. Finally, all patients are given systemic anticoagulation during division of the pulmonary artery and pulmonary vein. This potentially increases the risk of bleeding in the perioperative period.

Although donor lobectomy was performed on young, healthy persons, the incidence of perioperative complications associated with donor lobectomy is clearly higher than that of standard lobectomy<sup>15</sup> and approximates the incidence of complications previously reported with sleeve lobectomy. For instance, the incidence of bronchial stump fistulas in this series (3/62, 4.8%) is similar to the 3.0% incidence after sleeve lobectomy previously reported by Tedder and associates<sup>16</sup> and the 5.6% incidence reported by Kawahawa and coworkers.<sup>17</sup> The figure is higher than the 0.9% incidence reported by Vester and colleagues<sup>18</sup> in patients undergoing standard lobectomy. Interestingly, the incidence of postoperative bronchial stump fistulas in this series is higher than that in our previously reported experience after both sleeve resection and pneumonectomy for non-small cell lung cancer.<sup>19</sup>

The management of end-stage lung disease necessitating transplantation remains a significant challenge. Although living donor lobectomy increases the potential availability of suitable lungs for transplantation, the morbidity associated with the operation is high and

must be considered when potential living donors are being counseled. On the basis of our experience, we would continue to reserve living donor lung transplantation for selected recipients unable to wait for cadaveric lung allografts when suitable lobar donors are available.

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## Discussion

**Dr Vaughn A. Starnes** (*Los Angeles, Calif*). I would like to congratulate Dr Battafarano and his colleagues from Washington University on bringing to our attention the potential risk of living related donation in lung transplantation. In their series of 62 live donors, 10 patients had major complications and 38 had minor ones. The candor of this report can only be congratulated, but the message of using living donors as a last resort needs to be questioned.

In our institution we have performed lobectomies on 185 donors for transplantation. We have encountered 12 major complications for an incidence of 6.5%. The complications included pericarditis in 6, re-exploration for bleeding and air leak in 4, and pulmonary embolus versus thrombosis of a pulmonary artery in 2. No patient had permanent disability from donation.

To assess long-term outcome in the donor, we used a Rand 36-Item Health Survey to evaluate the physical and emotional well-being of 137 of these patients. The results indicate that 99%, at an average follow-up of 3 years, had no regrets for donating, and 95% reported no physical or emotional limitations.

To further assess the merits of live donation lung transplantation, we should also look at the recipients. In our 93 recipients, the 72% survival at 1 year equals that of the cadaveric reports. In our pediatric subset of 29 patients, the 1-year survival is 80% and is superior to that of the cadaveric reports. More important, the quality of life has been excellent, and the incidence of bronchiolitis obliterans (8%) is far less than that in the cadaveric group. Therefore, we conclude that live donation for lung transplantation is safe, the quality of life in the recipient is excellent, and the rate of bronchiolitis obliterans appears to be much less. On the basis of our data, we would advocate expanding rather than limiting the indications for live-related donation.

I have two questions. In an attempt to reduce the complication rate in the donor and recognizing the complexity of the donor operation, we have developed two surgical teams at our institution: one removes the right lung and one removes the left lung. Have you developed a similar approach in your institution?

**Dr Battafarano.** Yes, that is the way we have done it in all 62 donors. There have been two separate operating room teams for each donor and obviously a separate operating team for the recipient.

**Dr Starnes.** Do these surgical teams operate on only one lung or the other?

**Dr Battafarano.** We do not have a surgeon who does only right lower lobes and one who does only left lower lobes. We do alternate. However, there are two operating surgical teams for each individual donor.

**Dr Starnes.** We have found that the complexity and the anatomic variations on these two sides are amazing. We do have one team that does one side and one team that does the other side. They are specialists, and that seems to have limited the number of complications.

On the basis of your data, has your team modified any particular techniques that they are using to remove these lobes?

**Dr Battafarano.** I think we pay a lot more attention to the bronchial closure. To obtain maximal length for the recipient, we have a short donor oblique bronchotomy, which is closed with small bites under tension, and then we cover all of the bronchial closures with pleural flaps. Because of the initial experience with some of the bronchial stump fistulas, we are much more careful about making sure that we close that bronchus without tension and also are more aware when we actually perform the donor bronchotomy that we give ourselves adequate length on the donor bronchus for closure.

**Dr Douglas J. Mathisen** (*Boston, Mass*). John Wain at our institution has a smaller experience in living related donor lung transplantation. On at least one occasion, he had to reimplant the middle lobe bronchus, much as you would do for a sleeve lobectomy, because of the problems of doing a right lower lobectomy and the takeoff of the middle lobe. With the oblique line of transection of the bronchus and the tension created, I would think this is responsible for the fistulas and bronchial stenosis. Have you considered reimplanting the middle lobe bronchus to avoid this circumstance?

**Dr Battafarano.** We do not do it routinely, but we recently had a donor in whom the right middle lobe did not expand when we closed the bronchus. Thus we did a sleeve reconstruction of the middle lobe bronchus end to end to the bronchus intermedius. We had to do that in only one case.

**Dr Robbin G. Cohen** (*Los Angeles, Calif*). I was also interested in your bronchial stump complications and am curious about why the stump was closed under tension. If you transect the bronchi at a proper angle, which is about 45 degrees, and then resect that cartilaginous spur at the right middle lobe, the ends come together very nicely with no tension at all. We have closed about 180 of these and have yet to have a bronchial stump leak. What is your technique for bronchial transection that leads you to believe you are closing the bronchus under tension?

**Dr Battafarano.** In the majority of patients we thought we had a good closure, and that proved to be the case. (We had 3 bronchial stump fistulas in 62 patients.) However, at times we sensed that we were closing the bronchus under more tension than is optimal. In these cases, we removed a cartilaginous spur or did other things to reduce tension on the closure. Regardless, that closure is under much more tension than in the average lower lobectomy, in which the bronchus is divided distally at a point that allows good closure. I think a donor lobectomy is a different operation.