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Major Lung Resections Using Manual Suturing Versus Staplers During Fiscal Crisis

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During fiscal crisis there was a period of shortage of staplers in our hospital, which drove us to manual suturing of bronchi and pulmonary vessels during major lung resections. We present our experience during that period in comparison to a subsequent period when staplers became available again. A total of 256 lobectomies and 78 pneumonectomies using manual suturing (group A) were performed between September 2009 and September 2010, and were compared regarding surgical outcome with 248 lobectomies and 60 pneumonectomies using staplers (group B), performed between September 2011 and September 2012. Although we did not observe statistically significant differences but only a trend toward shorter operative time, for both lobectomies (P = 0.21) and pneumonectomies (P = 0.31) we actually noted savings of 41 and 47 minutes, respectively, in operative time using staplers (group B), in comparison with manual suturing (group A). We also observed a trend toward lower morbidity rates in group B patients who underwent lobectomy (10.48%) and pneumonectomy (20%) versus group A patients who underwent lobectomy (15.62%) and pneumonectomy (30.76%); we did not observe any substantial differences in the other surgical outcome variables, in patients' demographic, comorbidities, or in anatomic allocation of surgical procedures performed. The use of staplers offers safety with secure bronchial or vascular sealing, as well as reduction of operative time. Their unavailability at an interval during fiscal crisis, although it did not affect surgical outcome, revealed their usefulness and value.

Key words: Lung – Lobectomy – Pneumonectomy – Staplers

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The ideal technique of bronchial stump closure and of pulmonary hilum vessel ligation has concerned thoracic surgeons since the beginning of pulmonary surgery. Regarding bronchial stump closure, first Meyer, in 1909, advised his inversion technique, and Sweet, in 1945, suggested the single interrupted silk suture closure, which became the preferred method among thoracic surgeons compared with other techniques, in order to avoid the dreaded complication of bronchopleural fistula (BPF). In the late 1950s great strides were made by Russian surgeons who developed and reported first the "mechanical suturing" of the bronchus with staplers. The Russian metallic and reusable staplers, called UKB (bronchial stapler) and UKL (vascular stapler), were brought to the United States by Dr Mark Ravitch, who, after some modifications he personally designed and American manufacturers performed, used them intraoperatively on 139 patients in 1964. In 1970 Kirksey and coworkers reported on 147 patients who underwent pulmonary resection with the newly developed plastic and disposable American staplers, called Thoraco-Abdominal (TA), which continue to be manufactured today.[1,2] Nevertheless, the argument regarding manual bronchial suturing versus bronchial stapling has remained because proponents of both techniques recommend each one as reliable and safe, with notable short- and long-term results.[3–6] Similarly, the debate concerning pulmonary hilum vessel manual ligation versus stapled division lasted for many decades because of the reluctance to use vascular staplers due to the fear of fatal hemorrhage in cases of their malfunction. In 2002 Asamura and coworkers published a series of 842 mechanical vascular divisions using endoscopic staplers, with a 0.1% incidence of stapling failure, and in 2013 Yano and coworkers reported on 3393 pulmonary artery and vein stapling applications, with an adverse event rate of only 0.27%, resulting in the cessation of the alarm.[7–10]

In our hospital, during fiscal crisis there was a period of temporary shortage of stapling devices that drove us to manual suturing of bronchi and pulmonary hilum vessels during lobectomies and pneumonectomies, and in this study we present our experience during that time interval in comparison with a subsequent period when the supply of staplers was completely restored.

Patients and Methods

Prompted by the consequences of the fiscal crisis in our country, we conducted a retrospective study to evaluate its influence in our practice during a period when provision of our hospital, which is a state hospital, with stapling devices was suspended. In an effort to have homogenous groups for comparisons we selected only patients who underwent lobectomy or pneumonectomy for primary non–small cell lung cancer. Therefore, group A included 256 patients who underwent lobectomy and 78 patients who underwent pneumonectomy, with manual suturing of bronchi and pulmonary vessels, between September 2009 and September 2010; that period was called period A. They were compared regarding surgical outcome with group B, which comprised 248 patients who underwent lobectomy and 60 patients who underwent pneumonectomy, with stapling of bronchi and pulmonary vessels, during a subsequent period called period B (between September 2011 and September 2012), during which time the supply of staplers was completely restored. In the intermediate period, between October 2010 and August 2011, our hospital supply of staplers had been partially restored, and during operations we used both manual suturing and staplers, so their separate evaluation was not feasible.

In period A, with regard to manual suturing techniques, during pneumonectomies we used the classic continuous suturing in two layers (a horizontal mattress and an over-and-over above it), with absorbable 3-0 sutures for the main stem bronchus and nonabsorbable 4-0 sutures for the main pulmonary artery; the pulmonary veins were suture ligated. During lobectomies, branches of the lobar arteries and veins were suture ligated, lobar bronchi were manually sutured using the aforementioned technique for the main stem bronchi, and division of fused interlobar fissures of the lung was performed with the clamp and suture technique using 3-0 silk sutures, also in a fashion of horizontal mattress and an over-and-over above it.

In period B, as in all other periods in our institution except for period A, we used the known staplers from two companies, Ethicon Endo-Surgery (Cincinnati, Ohio) and Covidien (Mansfield, Massachusetts), without any predilection; during lobectomies we used TA staplers 30/4.8 mm (green) for lobar bronchus closure, and for fused interlobar fissure division we used gastrointestinal anastomosis (GIA) staplers of 100/3.5 mm (blue), or 100/4.8 mm (green), depending on tissue thickness; the branches of lobar arteries and lobar veins were suture ligated. During pneumonectomies we used TA staplers 45/4.8 mm (green) for main stem bronchus closure, and TA staplers 30/2.5 mm (white) for main pulmonary artery closure; pulmonary veins were suture ligated.

Statistical evaluation of our study patients' data was performed using Student *t*-test for continuous variables, and Pearson χ^2 test or Fisher exact test, as appropriate, for categoric variables. A *P* value of less than 0.05 was considered statistically significant.

Results

The study identified 277 men and 57 women with a mean age of 63.5 years (range, 51–78 years) in group A, who underwent 256 lobectomies and 78 pneumonectomies with manual suturing during period A; and 253 men and 55 women with a mean age of 64.3 years (range, 49–77 years) in group B, who underwent 248 lobectomies and 60 pneumonectomies using staplers during period B.

Anatomic allocation of surgical procedures performed, as shown in Table 1, was taken into account because right upper lobectomy is the most common lobectomy performed, and it is associated with more postoperative prolonged air leaks, and right pneumonectomy is associated with a higher incidence of BPF in comparison with left pneumonectomy, although we did not notice any statistically significant differences in the incidence of surgical procedures performed between the two study groups. Furthermore, patient demographics, surgical procedure duration, and comorbidities, such as hypertension, coronary artery disease, emphysema, diabetes mellitus, steroid use, and previous lung infections, which also influence surgical outcome, were considered too, and these presented in detail in Table 2; their statistical evaluation and analysis showed that besides a trend toward reduced mean duration of surgical procedures performed using staplers, all of the above variables did not differ statistically. However, the observed mean operative time benefits of 40.57 minutes regarding lobectomies and 46.96 minutes regarding pneumonectomies—in period A mean duration of lobectomies was 188.43 minutes, and mean duration of pneumonectomies was 173.46 minutes, and in period B mean duration of lobectomies was 147.86 minutes, and that of pneumonectomies was 126.5 minutes—pointed out that although there was only a trend toward shorter operative times for both lobectomies ($P = 0.36$) and pneumonectomies ($P = 0.31$), staplers hastened remarkably the duration of major lung resections in comparison with manual suturing.

Table 1 Anatomic allocation of lung resections performed with or without the use of staplers

Variable	Group A: manual suturing, n (%)	Group B: staplers, n (%)	*P* value
Lobectomies	256	248	—
(R) upper	85 (33.20)	92 (37.09)	0.35[a]
(R) middle	6 (2.34)	5 (2.01)	0.80[a]
(R) lower	38 (14.84)	29 (11.69)	0.29[a]
(R) bilobectomy	30 (11.71)	25 (10.08)	0.55[a]
(L) upper	72 (28.12)	62 (25)	0.42[a]
(L) lower	25 (9.76)	35 (14.11)	0.13[a]
Pneumonectomies	78	60	—
(R) pneumonectomy	32 (41.02)	27 (45)	0.63[a]
(L) pneumonectomy	46 (58.97)	33 (55)	0.63[a]

[a]Pearson χ^2 test.

Surgical outcome variables for both lobectomies and pneumonectomies—such as morbidity, mortality, reoperation for bleeding, intraoperative use of packed red blood cells, and hospital stay—in both patient groups were also considered and presented in detail in Table 3; their statistical analysis showed again that despite the lack of any statistically significant differences in all of the aforementioned surgical outcome variables there was a trend close to statistical significance, toward lower morbidity rates in group B patients, who underwent lobectomy (10.48%) and pneumonectomy (20%) with the use of staplers, versus group A patients, who underwent lobectomy (15.62%) and pneumonectomy (30.76%) using manual suturing ($P = 0.087$ and $P = 0.15$, respectively). Regarding reoperations for bleeding, the causes of bleeding in the 2 reoperated patients who underwent lobectomy with manual suturing (group A) were an intercostal artery injured during thoracotomy closure for one patient, and a bronchial artery that was cauterized and not ligated for the other patient; the cause of bleeding in the 1 reoperated patient of group B (patients who underwent lobectomy using staplers) was a bleeder in the chest wall following difficult dissection of dense pleural adhesions (he had a history of tuberculosis); in all 3 cases the causes of bleeding were unrelated to manual or mechanical suturing techniques.

Discussion

In the beginning of thoracic surgery, the technique of manual bronchial stump closure using single interrupted silk sutures and pleural flap reinforce-

Table 2 Demographics, comorbidities, and surgical procedure durations of study patients who underwent lung resection with or without the use of staplers

Variable	Group A: manual suturing	Group B: staplers	*P* value
Age, y, mean (range)	63.5 (51–78)	64.3 (49–77)	0.39[a]
Female sex, n (%)	57 (17)	55 (18)	0.74[b]
Smoking habits, n (%)	324 (97)	302 (98)	0.37[b]
Coexisting diseases (hypertension, CAD, DM, COPD, steroid use, Tbc or other lung infections)	110 (33)	108 (35)	0.83[b]
Lobectomies, n	256	248	—
Pneumonectomies, n	78	60	—
Duration of lobectomies, min, mean (range)	188.43 (120–340)	147.86 (90–280)	0.36[a]
Duration of pneumonectomies, min, mean (range)	173.46 (100–250)	126.50 (90–200)	0.31[a]

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; Tbc, tuberculosis.

[a]Student *t*-test.

[b]Pearson χ^2 test.

ment, prevailed in the United States and Europe, but the development of various mechanical stapling devices by Russian surgeons in 1957 was a breakthrough. Their clinical application on several thousands of patients, by Amosov and Berezovsky in 1961, had a huge impact on modern thoracic surgery, and they were the first to report on the advantages of bronchial stapling: its simplicity, expediency, and safety. In 1958, Ravitch visited Amosov in Kiev to observe him operating with staplers, but he was not allowed to bring even one of those staplers back to the United States; however, on his way back home, he accidentally found and bought a UKB-25 stapler in a general store outside of Kiev, and, returning to Baltimore, he set about using it on animals, and working with American manufacturers (USSC, Norwalk, Connecticut), he managed to implement many technical modifications and improvements. His first clinical series was published in 1964, reporting on his results using a modified UKB-25 stapler in 139 patients with tuberculosis. In 1970, Kirksey and coworkers reported on 147 pulmonary resections with the newly developed American staplers, which were plastic and disposable, had sterilized preloaded cartridges, and could deliver different lengths of staple lines (TA-30, TA-55), giving birth to a new era of mechanical stapling, because those staplers continue to be manufactured even today, with the latest technical innovations added in order to face industry competition.[1,2] Nevertheless, the debate of manual versus mechanical bronchial suturing has lasted through today, because proponents of the former advise that it is a reliable, safe, and inexpensive technique with good results in all situations, provided that the surgeon is quite experienced; on the other hand, bronchial stapler advocates recommend those instruments as also being reliable, safe, and easy to apply, and also capable of being used by junior surgeons, with excellent short- and long-term results.[3–6]

In an experimental study, Graeber and colleagues[3] in 1991 tested the pressures required to cause leakage in manually sutured or stapled closed bronchi and pulmonary arteries in human cadavers and pigs, and reported that stapler closure was as safe as suture closure.[3] Weissberg and Kaufman[4] in 1992 noted a 4.5% incidence of BPF after manual suturing of bronchi versus 0% after stapler closure, in patients undergoing pulmonary resection for lung cancer, and reported that bronchial stapling was safer and quicker than bronchial suturing. In contrast, Al-Kattan and coworkers[5] in 1994 reported a 1.3% incidence of BPF after 530 consecutive pneumonectomies using a uniform hand-suturing technique, and concluded that bronchial manual suturing is a cheap and reliable technique with good results in the hands of experienced surgeons. In our study, we had only 1 case of BPF in each group of patients who underwent pneumonectomy (78 patients with manual bronchial suturing and 60 with bronchial stapling), but both study periods were short (1 year each), and pneumonectomy numbers were small for any conclusions to be drawn. With regard to endoscopic bronchial staplers—which came out in parallel with the widespread rise in the practice of video-assisted thoracic surgery lobectomy—Asamura and coworkers[9] in 2002 reported on 533 consecutive bronchial closures (9% manually sutured and 91% stapled closures), with a

Table 3 Comparison of surgical outcome variables of study patients who underwent lung resection with or without the use of staplers

Variable	Group A: manual suturing	Group B: staplers	*P* value
Lobectomy 30-d mortality, n (%)	4 (1.56)	3 (1.20)	1[a]
Pneumonectomy 30-d mortality, n (%)	5 (6.4)	3 (5)	0.72[a]
Lobectomy causes of death, n	4 (pneumonia, n = 2; PE, n = 1; MI, n = 1)	3 (pneumonia, n = 1; PE, n = 1; MI, n = 1)	—
Pneumonectomy causes of death, n	5 (ALI, n = 1; pneumonia, n = 2; PE, n = 1; MI, n = 1)	3 (ALI, n = 1; MI, n = 1; pneumonia, n = 1)	—
Lobectomy 30-d morbidity, n (%)	40 (15.62)	26 (10.48)	0.087[b]
Pneumonectomy 30-d morbidity, n (%)	24 (30.76)	12 (20.00)	0.15[b]
Lobectomy complications list, n	40 (AF, n = 10; PAL, n = 11; chylothorax, n = 2; atelectasis, n = 6; pneumonia, n = 3; stroke, n = 1; ileus, n = 2; DVT, n = 2; PE, n = 2; TIA, n = 1)	26 (AF, n = 9; PAL, n = 6; chylothorax, n = 1; atelectasis, n = 2; stroke, n = 1; TIA, n = 1; pneumonia, n = 1; MI, n = 1; PE, n = 1; DVT, n = 2; ileus, n = 1)	—
Pneumonectomy complications list, n	24 (AF, n = 9; chylothorax, n = 2; atelectasis, n = 4; DVT, n = 1; pneumonia, n = 4; PVO, n = 1; BPF, n = 1; stroke, n = 1; TIA, n = 1)	12 (AF, n = 6; stroke, n = 1; atelectasis, n = 1; pneumonia, n = 1; BPF, n = 1; TIA, n = 1; DVT, n = 1)	—
Lobectomy: reoperation for bleeding, n (%)	2 (0.78)	1 (0.4)	1[a]
Pneumonectomy: reoperation for bleeding, n (%)	0 (0)	0 (0)	—
Lobectomy: intraoperative PRBC units, mean ± SD	0.31 ± 0.790	0.14 ± 0.496	0.49[c]
Pneumonectomy: PRBC units, mean ± SD	0.44 ± 1.0	0.38 ± 0.90	0.43[c]
Lobectomy: length of stay, d, mean ± SD	9.382 ± 4.28	7.995 ± 3.25	0.49[c]
Pneumonectomy: length of stay, d, mean ± SD	12.641 ± 4.00	11.8 ± 4.23	0.41[c]

AF, atrial fibrillation; ALI, acute lung injury; DVT, deep vein thrombosis; PE, pulmonary embolism; PRBC, packed red blood cells; TIA, transient ischemic attack.

[a]Fisher exact test.

[b]Pearson χ^2 test.

[c]Student *t*-test.

4% incidence of BPF after manual suturing versus 1% after stapling, and a 3.7% stapling failure rate, concluding that bronchial endostaplers in comparison with conventional staplers are equally safe.[6] We had no experience with endoscopic bronchial staplers in our study.

Apart from bronchial closure, the dilemma about suture ligation of major pulmonary arteries and veins versus stapled division, using vascular staplers (TA-type or endoscopic staplers), has endured similarly, particularly throughout the last decade, when the universal application of endostaplers during video-assisted thoracoscopic surgery lobectomy procedures escalated, despite safety concerns regarding potentially life-threatening complications in the event of stapling failure. Sugarbaker and Mentzer[7] in 1992 published a technique for pulmonary artery stapling using two successive applications of the same stapler, and reloading without removing it, in order to address surgeons' reluctance to use vascular staplers of the TA-type in the pulmonary hilum. In contrast, Craig and Walker[8] in 1995 reported on 2 of 57 patients who underwent video-assisted thoracoscopic surgery lobectomy, who needed expeditious thoracotomy because of massive bleeding ensuing from vascular stapling failure, suggesting that video-assisted thoracoscopic surgery lobectomies should be performed only in specialized centers. Nevertheless, in 2002 Asamura and coworkers[9] published a series of 842 mechanical vascular divisions in 603 patients who underwent pulmonary resection, with endostaplers used in 98.2% of cases and conventional TA-type used in 0.2%, with only a 0.1% incidence of stapling failure; the authors reported that endostaplers were highly reliable. And in 2013 Yano and coworkers,[10] having analyzed 3393 pulmonary artery and vein stapling applications on 4495 patients, with only a 0.27% adverse event rate, reported with reassurance that stapling of the pulmonary vasculature was safe. In our study we used only the conventional TA-30 vascular staplers for main pulmonary artery closures, during pneumonectomies, without any adverse events. As mentioned, using TA-type bronchial and vascular staplers—and GIA-type staplers used for division of fused interlobar lung fissures—during lobectomies, we noted a reduction of average surgical procedure time to 41 minutes regarding lobectomies and 47 minutes regarding pneumonectomies, in procedures performed using staplers versus those performed with manual suturing. Although our observations did not reach statistical significance, they demonstrated a huge practical benefit associated with the use of staplers; in addition, staplers were proven to be safe, reliable, and valuable because not only did we not observe any adverse effects during their intraoperative application, but morbidity rates associated with their use were noted to have a downward trend, resulting from shorter operative times and fewer surgical manipulations, particularly concerning older patients, and patients with emphysematous lungs and other comorbidities.

The use of staplers has long contributed significantly in thoracic surgery, offering a number of advantages, such as ease of application and training of junior surgeons in their use, safety with secure vascular or bronchial sealing, operative time savings, and less morbidity and mortality. However, from the educational and training point of view, junior doctors learning to use only staplers are missing the experience of classic manual suturing techniques; and this became obvious in our hospital during a period of stapler shortage, when junior surgeons gained valuable experience as they were helped by their seniors during operations. However, this situation can ensue in any hospital during a crisis period; therefore, it is essential for junior surgeons to have exposure and training to classic surgical suturing techniques.

With regard to the drawbacks of our study, because it was retrospective and observational it has inherent selection and information biases, such as short comparison periods with relatively small numbers of operative cases. However, arising from the above statistical evaluation of patient demographics, comorbidities, anatomic allocation of surgical procedures performed, and surgical outcome variables, as presented in Tables 1, 2, and 3, the fact that besides mean duration of surgical procedures and morbidity rates, the remaining variables were all noted to have no substantial differences, indicates homogenicity and unbiased patient selection; as has been reported in the literature, age, emphysema, previous lung infections causing dense pleural adhesions, diabetes, right upper lobectomy, and right pneumonectomy are considered main risk factors for such complications as postoperative atelectasis, pneumonia, air leaks, BPF, and poor outcome.[6,11,12]

In conclusion, the unavailability of staplers at an interval during fiscal crisis, in our hospital, did not significantly impact surgical outcome, but it revealed the staplers' usefulness and value because we observed a trend toward considerable operative time reduction and lower morbidity rates following lobectomies or pneumonectomies for lung cancer; and this contributed in the consolidation of our opinion favoring their use. Moreover, as we were forced to perform manual suturing during a period of stapler unavailability, we were, on the one hand, experiencing the disadvantages of their shortage, but on the other hand, we experienced the merit of classic surgical principles and techniques regarding manual suturing of major bronchi and vessels in the lung hilum.

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