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Simultaneous lung resection via a transdiaphragmatic approach in patients undergoing liver resection for synchronous liver and lung metastases

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Abstract

Background—For patients with synchronous liver and lung metastases from colorectal cancer, the invasiveness of adding thoracic to abdominal surgery is an obstacle to concurrent liver and lung metastasectomy. We developed a simple technique to resect lung lesions via a transdiaphragmatic approach without thoracic incision in patients undergoing liver metastasectomy.

Methods—Sixteen patients with synchronous liver and unilateral lung metastases underwent transdiaphragmatic wedge resection of lung lesions simultaneous with liver metastasectomy. Short-term surgical outcomes were compared with those in 102 patients treated with conventional unilateral wedge resection for colorectal lung metastases.

Results—Twenty peripheral (<3 cm from the pleura) lung lesions from various locations in the lung were resected via transdiaphragmatic approach. No conversions to conventional approach were required. The median tumor number and size were 1 (range, 1–3) and 8 mm (range, 3–30 mm), respectively. Transdiaphragmatic resection reduced median operative blood loss compared with conventional resection (0 mL vs 50 mL [$p<0.001$]) and reduced median length of hospital stay compared with staged liver and lung resection (6 days vs 11 days [$p<0.001$]). Surgical duration and rates of lung-related morbidity and positive surgical margin were similar between the transdiaphragmatic and conventional groups (104 min vs 105 min [$p=0.61$], 13% vs 4% [$p=0.15$], and 6% vs 5% [$p=0.73$], respectively).

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Conclusions—Simultaneous transdiaphragmatic resection of peripheral lung lesions is safe in patients undergoing liver resection. The low-invasive transdiaphragmatic approach facilitates aggressive surgical treatment for synchronous liver and lung metastases.

Keywords

synchronous liver and lung metastases; lung metastasectomy; transdiaphragmatic approach

Introduction

The 2 most common sites of metastases from colorectal cancer are the liver and lung.^{1, 2} The synchronous presence of liver and lung metastases from colorectal cancer has been recognized as advanced tumor dissemination, which leads to the paucity of candidates for an aggressive surgical approach.^{3–8} However, recent advances in multidisciplinary treatment are dramatically changing the prognostic impact of colorectal lung metastases.^{9, 10} We recently demonstrated that the long-term prognosis of patients who underwent surgical treatment for liver and lung metastases from colorectal cancer was better than the prognosis of patients with liver-only metastases treated with resection of liver metastases alone.⁹ The presence of resectable lung metastases is no longer a predictor of inferior prognosis, and the clinical significance of aggressive surgery for synchronous liver and lung metastases needs to be re-evaluated.

The major obstacle to performing resection of liver and lung metastases is the invasiveness of adding thoracic surgery to liver resection. In terms of patient quality of life and cost-effectiveness, simultaneous liver and lung resection with 1 hospitalization and 1 induction of anesthesia might be preferable; however, both an abdominal incision and a thoracic incision are inevitable even when minimally invasive thoracoscopy is used, which convinces some authors to perform staged lung resection—i.e., to have patients recover from hepatectomy before lung resection is performed.^{3–6}

In an attempt to reduce the invasiveness of simultaneous liver and lung metastasectomy, we developed a simple and novel technique to resect synchronous lung lesions via a transdiaphragmatic (transdiaphragmatic) approach in patients undergoing liver resection for metastatic disease. When the thoracic cavity is approached from the abdominal surgical field via the diaphragm, a thoracic incision can be avoided. In this study, we reviewed our experience with the transdiaphragmatic approach and investigated the safety and feasibility of this technique by comparing the surgical outcomes with those of conventional lung metastasectomy.

Methods

A prospectively maintained database at The University of Texas MD Anderson Cancer Center was reviewed for 2282 patients who underwent liver resection for metastatic liver disease during the period from January 2000 through June 2013. Within this group, 23 patients underwent lung resection simultaneous with the liver resection. Of these 23 patients, 7 patients with bilateral lung lesions, central lesions to be resected by lobectomy, or history of previous lung resection underwent conventional liver and lung resection with thoracic

incision. The remaining 16 patients (70%) underwent transdiaphragmatic resection of unilateral lung lesions with 1 or 2 wedge resections. Institutional Review Board approval was obtained before data retrieval.

We applied transdiaphragmatic lung resection to peripheral lung lesions whose size was larger than 8 mm in the preoperative imaging regardless of the lung lobes involved.

Surgical procedures

General anesthesia was induced with placement of a double-lumen endotracheal tube to achieve 1-lung ventilation. In all patients treated with the transdiaphragmatic approach, liver and lung metastasectomy was performed with the patient in the supine position regardless of the side of the lung lesions. Laparotomy and liver resection were performed prior to lung metastasectomy to evaluate for abdominal carcinomatosis and the resectability of liver metastases. Abdominal incisions were bilateral or right subcostal, inverted L, J-shaped, or midline according to the procedures for liver resection. No additional incisions were made to perform transdiaphragmatic lung metastasectomy. After liver resection was completed, the lung with metastases was fully deflated, and the hemidiaphragm was circumferentially cut open over the central tendon with care taken not to damage the phrenic nerve. The inferior pulmonary ligament was cut with electrocautery under direct visualization to mobilize the lung. Meticulous finger palpation was conducted to find lung lesions in the whole unilateral lung. Lung resection was conducted with palpation and visualization of surgical field as well using endoscopic 45-mm or 60-mm staplers to obtain a sufficient pathologic margin. After confirmation of no air leakage or bleeding, a 24-Fr thoracic tube was placed, and then the diaphragm was closed with running suture. Finally, the abdominal wall was closed in a usual manner.

Comparison of outcomes between transdiaphragmatic and conventional lung metastasectomy

Short-term surgical outcomes were compared between transdiaphragmatic lung metastasectomy and conventional lung metastasectomy performed during the same period at our institution. Using the previously mentioned prospectively maintained database at MD Anderson Cancer Center, and after obtaining Institutional Review Board approval, we identified 246 patients who underwent first lung metastasectomy for colorectal lung metastases. Among them, 102 patients who had 1 or 2 wedge resections for unilateral lesions (to match the surgical procedures in the patients who underwent transdiaphragmatic resection) were selected as the control population. Patients who had bilateral lesions or who underwent lung lobectomy, segmentectomy, or 3 or more wedge resections were excluded. Patients who underwent simultaneous resection of primary or liver lesions were also excluded. Video-assisted thoracic surgery was performed in 19 patients (19%). Among the 102 patients in the control population, 43 patients (42%) had undergone prior liver resection for colorectal liver metastases. Among these patients, 35 had medical records available, and the combined length of hospital stay for these patients, including the length of hospital stay after liver resection, was compared with the length of hospital stay in the patients who underwent simultaneous liver and transdiaphragmatic lung metastasectomy.

In patients treated with a transdiaphragmatic approach, the duration of surgery and extent of blood loss were counted from the time of deflation of the corresponding lung to the end of surgery and determined by reference to anesthesia records, except for 2 patients whose records were not available.

Statistical analysis

Categorical variables were compared using the chi-squared test. Continuous variables were compared using the Mann–Whitney U test and expressed as median (range). A value of $p < 0.05$ was considered statistically significant. Statistical analyses were performed using the software IBM SPSS Statistics, version 19 (IBM, Armonk, NY).

Results

The details of the 16 patients who underwent lung metastasectomy via a transdiaphragmatic approach are summarized in Table 1. Fifteen patients had synchronous liver and lung metastases from colorectal cancer. In the remaining patient (patient 8), the primary tumor was granular cell carcinoma of the pelvis. Eight patients (50%) underwent repeat liver resection for recurrent liver metastases. All lung lesions detected by preoperative imaging were resected via transdiaphragmatic approach without conversion to conventional lung metastasectomy. Median size of the resected tumors was 10 mm (range, 5–30 mm).

Lung tumor characteristics

The median number of resected lung tumors was 1 (range, 1–3). The distance from the pleura to the center of the most distant tumor was 30 mm or less in all patients. The tumor distribution is summarized in Figure 1. One lesion (in patient 14) that had not been found preoperatively was detected by manual palpation and was diagnosed as osseous metaplasia.

Outcomes of simultaneous liver metastasectomy and transdiaphragmatic lung metastasectomy

There were no deaths within 90 days of simultaneous liver resection and transdiaphragmatic lung metastasectomy. Median surgical duration and estimated blood loss of 7 patients who had lung lesions located in the upper lung were similar to those of others who had lung lesions located in the middle or lower lung (99 min. vs 105 min [$p = 0.65$], 0 mL vs 0 mL [$p = 0.19$], respectively). Lung-related complications were observed in 2 patients (13%). One patient (patient 9) had a postoperative air leakage, which resolved spontaneously on the second postoperative day. Another patient (patient 12) had an air leakage after the removal of the chest tube, which was managed by chest tube reinsertion. The patient was discharged on the sixth postoperative day with a Heimlich valve. The chest tube was removed on the tenth postoperative day in the outpatient clinic. No patients had lung-related complications at the routine check-up performed median 17.4 months after surgery (range, 2.3–57.6 months).

Comparison of outcomes between patients undergoing transdiaphragmatic and conventional lung metastasectomy

Outcomes of surgery in patients undergoing transdiaphragmatic and those undergoing conventional lung metastasectomy are summarized in Table 2. There were no significant differences between 2 groups in lung tumor characteristics and the number of wedge resections. Duration of surgery and the incidence of lung-related complications were also similar between the 2 groups. The estimated blood loss during surgery was lower in the transdiaphragmatic group. The length of hospital stay in patients treated with the transdiaphragmatic approach was shorter than the total length of hospital stay in the patients undergoing conventional staged liver and lung metastasectomy, including the stay after liver resection. The incidence of pathological tumor exposure at surgical margins was similar in the 2 groups.

Discussion

We developed a simple and novel technique to perform synchronous lung metastasectomy via a transdiaphragmatic approach in patients undergoing liver resection for metastatic disease. This technique was safely performed in 16 patients with peripheral lung lesions regardless of the lung lobes involved or the history of previous liver resection. Our comparative study demonstrated that the transdiaphragmatic approach reduced operative blood loss compared with conventional lung metastasectomy and reduced the length of hospital stay compared with staged liver and lung metastasectomy and that surgical duration, postoperative morbidity, and oncological radicality were similar for our transdiaphragmatic approach and conventional lung metastasectomy.

The most important benefit of the transdiaphragmatic approach is that it avoids thoracic incisions for lung metastasectomy. The negative impact of thoracic incisions on physical quality of life has been reported in patients undergoing liver resection with thoracotomy to obtain better surgical fields.¹¹ In our study, the low invasiveness of the transdiaphragmatic approach was demonstrated by reduced blood loss compared with conventional lung resection and shorter hospital stay compared with staged liver and lung resection. Although we did not compare our transdiaphragmatic approach with conventional simultaneous liver and lung resection because of the paucity of patients undergoing conventional simultaneous liver and lung resection and the difference of surgical procedures, we speculate that further investigation, including quality-of-life or economical assessment, would confirm the advantage of our low-invasive transdiaphragmatic approach for simultaneous liver and lung resection.

Lung metastasectomy via a transdiaphragmatic approach is a reasonable technique considering that metastatic lung disease tends to occur at the periphery of the lung.^{12–14} Minimally invasive wedge resection has been accepted as a standard surgical procedure for lung metastases to preserve pulmonary function as well as health-related quality of life after thoracic surgery.^{15–17} At our institution, no definitive criteria regarding the depth of lung lesions were used to select patients for a transdiaphragmatic approach; however, this retrospective analysis confirmed that transdiaphragmatic resection with manual palpation

can be performed without conversion to conventional approach in patients with peripheral (<3 cm from the pleura) lesions regardless of the location in the lung.

Liver and transdiaphragmatic lung resection was safely performed in patients with a history of previous liver resection, which is a strength of our novel approach as a treatment strategy for patients with colorectal liver metastases. Half of the patients in our series (8 of 16) were undergoing repeat hepatectomy at the time of simultaneous resection of lung lesions. Moreover, 2 patients underwent a third hepatectomy for recurrence. Repeat liver resection improves prognosis in patients with recurrent colorectal liver metastases.^{18–20} However, further recurrence after a first repeat liver resection remains a major oncological challenge and compels multiple repeat hepatectomy.^{18–20} The results of this study demonstrated that the transdiaphragmatic approach is applicable to patients with synchronous lung and recurrent liver metastases.

A limitation of the transdiaphragmatic approach is its narrow visual field in the thoracic cavity. Detection and removal of lung lesions were accomplished with manual palpation and visualization of the surgical field. However, we found that the transdiaphragmatic approach had safety and technical complexity comparable to those of conventional lung metastasectomy, as demonstrated by the equivalent lung-related morbidity and surgical duration, respectively. The impact of liver resection on thoracic cavity has been investigated in patients undergoing liver resection via a transthoracic approach.^{21–29} The available evidence shows that the incidence of overall and respiratory-related complications is similar among patients undergoing liver resection via the transthoracic and conventional abdominal approach.^{21, 22}

The oncological safety of the transdiaphragmatic approach was underscored by the fact that the incidence of pathological tumor exposure at the surgical margin was similar to that after the conventional approach. In this study, comparison of long-term prognosis was not conducted because of the difference in tumor characteristics in terms of timing of appearance of liver and lung metastases (synchronous vs metachronous) between the 2 groups. As for the detection of lung lesions, manual palpation is the most sensitive procedure to detect small lung lesion,^{13, 16, 30} which is one of the advantages of the transdiaphragmatic approach compared to conventional thoracoscopic approach. We found all lung lesions detected by preoperative imaging and an additional lesion by manual inspection. Some authors speculated that additional nodules detected by palpation did not have impact on long-term survival because of the high false-positive rate of small lung lesions as one additional lesion resected in this study.^{31, 32} However, a recent series demonstrated that manual palpation via open thoracotomy increases the number of pathologically confirmed malignant lesions compared to a thoracoscopic approach,³³ which supports the oncological benefit of the transdiaphragmatic approach that enables meticulous manual inspection of the unilateral lung.

Our simultaneous transdiaphragmatic approach to lung metastasectomy could lead to improved understanding of the clinical significance of synchronous liver and lung metastases from colorectal cancer. The largest series demonstrated that 32 patients with synchronous liver and lung metastases had a worse prognosis than 99 patients with

metachronous liver and lung metastases.⁴ However, that study was conducted between 1981 and 2000, before modern chemotherapy was available. Given that the multidisciplinary approach is dramatically changing the treatment strategy for stage IV colorectal cancer, the prognostic benefit of liver and lung metastasectomy needs to be re-evaluated. The low invasiveness of our transdiaphragmatic technique can facilitate an aggressive surgical approach to liver and lung metastases.

Our low-invasive transdiaphragmatic approach is also applicable to patients with indeterminate lung lesions. The enhanced resolution of computed tomography results in detection of synchronous indeterminate lung lesions in up to 43% of patients undergoing liver resection for colorectal metastases.^{10, 34} Preoperative diagnosis of indeterminate lung lesions is difficult with positron emission tomography scans or fine-needle aspiration,^{35–37} and the presence of suspicious lung lesions might previously have precluded curative liver resection in some patients who actually had benign lung lesions. Transdiaphragmatic technique can offer such patients a chance for surgery that may improve survival...

In conclusion, simultaneous liver and transdiaphragmatic lung metastasectomy was safely performed in 16 patients with synchronous liver and lung lesions. This technique could further elucidate the prognostic impact of colorectal lung metastases and expand the candidates for curative liver resection for colorectal liver metastases.

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Figure 1. Location of 20 Lung Lesions

Locations of lesions resected by simultaneous transdiaphragmatic lung metastasectomy in patients undergoing resection of liver metastases. Bold numbers indicate the number of lesions resected in each lung lobe. Numbers in parentheses indicate mean diameter of tumors (mm) and mean distance from the pleura to tumors (mm), respectively.

Table 1

Details of 16 Patients Who Underwent Transdiaphragmatic Lung Metastasectomy

Pt. no.	Age, yr	Sex	Liver resection				Lung lesions						Length of hospital stay, days		Surgical margin, mm	
			Procedure	Redo*	Incision	No.	Size, mm	Distance, mm [†]	Location	Resection	Duration, min	EBL, mL	Complication	Other morbidity		
1	54	M	Lt Hx	-	Bilateral subcostal	1	15	17	RL	1	NA	NA	-	-	7	13
2	70	M	Partial	1st repeat	Bilateral subcostal	1	15	26	RL	1	NA	NA	-	-	8	1
3	73	M	Partial	1st repeat	Right subcostal	1	20	19	RM	1	124	10	-	SSI, ascites	6	8
4	40	M	Rt Hx	-	Bilateral subcostal	1	23	10	RM	1	83	NA	-	-	8	2
5	55	M	Lt Hx	-	Inverted L	1	30	15	RL	1	137	75	-	-	6	3
6	57	M	Partial	2nd repeat	Midline	1	8	24	RU	1	77	0	-	-	5	4
7	45	F	Partial	-	Midline	1	10	13	LL	1	86	0	-	-	6	1
8 [‡]	58	F	Partial	-	Inverted L	1	10	16	RL	1	99	0	-	-	4	8
9	75	F	RFA	1st repeat	Right subcostal	1	5	19	RL	1	86	100	Minor air leak	-	7	10
10	57	M	Rt Hx	-	Inverted L	1	24	15	RU	1	102	0	-	CVA	12	12
11	63	F	Partial	1st repeat	Inverted L	1	6	7	RU	1	132	0	-	-	6	1
12	49	F	Partial	1st repeat	Inverted L	1	10	21	LU	1	105	0	Air leak Reinsertion	-	6	2
13	54	M	Partial	2nd repeat	Inverted L	1	5	5	RM	1	121	0	-	-	5	1
14	54	F	Lt Hx	-	Inverted L	2	6	14	RU, RL	2	90	0	-	-	5	9
15	55	F	Lt Hx	-	Inverted L	2	15	13	LU, LL	2	156	10	-	-	4	+
16	40	M	Rt Hx	1st repeat	J	3	5	13	RM, RL	2	131	0	-	-	4	1

* Repeat resection for recurrent liver metastases.

† Distance from the pleura to the center of the most distant tumor.

‡ This patient's primary tumor was granular cell carcinoma of the pelvis.

EBL, estimated blood loss; Lt Hx, left hepatectomy; Rt Hx, right hepatectomy; RL, right lower lobe; RM, right middle lobe; RU, right upper lobe; LU, left upper lobe; LL, left lower lobe; NA, not available; SSI, surgical site infection; CVA, cerebral vascular accident.

Patient Characteristics and Surgical Outcomes in Patients Who Underwent Transdiaphragmatic and Those Who Underwent Conventional Lung Metastasectomy

Table 2

	Trans-Diaphragmatic n=16 (%)	Conventional n=102 (%)	p Value
Age	55 (40–75)	60 (39–83)	0.17
Sex (m/f)	9/7 (56/44)	49/45 (52/48)	0.36
Number	1 (1–3)	1 (1–5)	0.99
Size (mm)	10 (3–30)	15 (5–100)	0.09
Resection (1/2)	13/3 (81/19)	81/21 (79/21)	0.87
Surgical duration (min)	104 (77–156)	105 (35–232)	0.61
EBL (mL)	0 (0–100)	50 (0–285)	<0.001
Transfusion	0 (0)	0 (0)	1.00
Lung-related complication	2 (13)	4 (4)	0.15
Lung-related complication (vs. VATS)*	2 (13)	0 (0)	0.06
LOS (day)	6 (4–12)	4 (1–10)	0.001
Total LOS after liver and lung resection** (day)	6 (4–12)	11 (7–21)	<0.001
Positive surgical margin	1 (6)	6 (5)	0.73

EBL, estimated blood loss; VATS, video-assisted thoracic surgery; LOS, length of hospital stay.

* Lung-related complication was compared in 19 patients who underwent VATS.

** LOS including postoperative stay after the previous liver surgery, available in 35 of 43 patients treated with prior liver resection.