

Surgical Outcomes in Utilization of Three-Dimensional Image Simulation for Segmentectomy Planning in Patients with Stage IA1-2 Non-small Cell Lung Cancer

Objective: To evaluate the perioperative and post-operative outcomes of using three-dimensional reconstruction modeling (3DR) in preoperative planning of segmentectomy in clinical stage IA1-2 non-small cell lung cancer (NSCLC) patients.

Methods: Patients with clinical stage IA1-2 NSCLC who underwent segmentectomy either with (3DR) or without (Control) three-dimensional imaging reconstruction from July 2021 to February 2025 at a single institution were identified from a prospectively maintained surgical database. Patients with previous thoracic surgery in the ipsilateral lung and patients with pre-resection localization procedure were excluded. Fisher's exact test and Wilcoxon rank sum test were used to compare categorical and continuous variables respectively between the cohorts. A multivariable logistic regression model was used to assess the association between in-hospital complications and clinical variables.

Results: In total, 253 patients underwent segmentectomy for clinical stage IA1-2 NSCLC. There were 125 patients in the 3DR group and 128 patients in the Control group. 3DR was more commonly used in patients with tumors in right upper lobe (24% vs 13%), left apical trisegment (36% vs 31%) and basilar segments (21% vs 16%, $p=0.007$). Open thoracotomy, either planned (0.8% vs 6.3%) or conversion (1.6% vs 3.1%), was less frequent in the 3DR group compared to the Control group ($p=0.050$). More robotic resections (82% vs 59%, $p<0.001$) and complex segmentectomies (60% vs 30%, $p<0.001$) were performed in the 3DR group. In regard to operative outcomes, there were no differences in the rate of additional margin resection (9.6% vs 13%, $p=0.431$), rate of complete R0 resection (98% vs 99%, $p=0.619$) or distance of closest margin (1.20 cm vs 1.20 cm, $p=0.371$) between the two groups. While there was no difference in overall operative times between the 3DR and Control groups (180 minutes vs 189 minutes, $p=0.217$), subgroup analysis of patients undergoing complex basilar segmentectomies demonstrated decreased operative time in the 3DR group compared to the Control group (181 minutes vs. 231 minutes, $p=0.13$). After excluding patients who had planned thoracotomy from the post-operative variable analysis, patients in the 3DR group had fewer in-hospital complications (9.7% vs 23%, $p=0.005$) and were less likely to require home oxygen on discharge (0 vs 5.0%, $p=0.013$). However, there were no differences in hospital length of stay (2 days vs 2 days, $p=0.821$), chest tube duration (1 day vs 2 days, $p=0.164$), rate of air leak (24% vs 32%, $p=0.196$) or rate of readmission within 30 days (3.2% vs 4.2%, $p=0.746$) between the two groups. After adjusting for clinical variables in a multivariable analysis, the use of 3DR (OR 0.42, 95% CI 0.20-0.89; $p=0.023$) remained the sole significant variable associated with a decrease in in-hospital complications (Table 1).

Conclusions: The application of three-dimensional reconstruction models to segmentectomy planning in stage IA1-2 NSCLC patients demonstrated a reduction in post-operative complications. While margin adequacy appeared similar between the two groups, use of 3DR may also be associated with decreased operative time in the setting of complex basilar segmentectomies.

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Table 1. Univariable Analysis of Clinical Variables and Post-operative Outcomes Between Patients With (3DR) or Without Three-Dimensional Imaging Reconstruction (Control) and Multivariable Analysis of In-hospital Complications Between Cohorts

Clinical variables	Overall N=253*	3DR N=125*	Control N=128*	p-value
Segment location				0.007
Left apical trisegment	85 (34%)	45 (36%)	40 (31%)	
Right upper lobe	46 (18%)	30 (24%)	16 (13%)	
Right middle lobe	2 (0.8%)	0	2 (1.6%)	
Lingula	19 (7.5%)	6 (4.8%)	13 (10%)	
Superior segment of lower lobe	54 (21%)	18 (14%)	36 (28%)	
Basilar segment	47 (19%)	26 (21%)	21 (16%)	
Segmentectomy complexity				<0.001
Simple segmentectomy	139 (55%)	50 (40%)	89 (70%)	
Complex segmentectomy	114 (45%)	75 (60%)	39 (30%)	
Surgical approach				0.050
Open	9 (3.6%)	1 (0.8%)	8 (6.3%)	
VATS	238 (94%)	122 (98%)	116 (91%)	
VATS converted to open	6 (2.4%)	2 (1.6%)	4 (3.1%)	
Robotic surgery	179 (71%)	103 (82%)	76 (59%)	<0.001
Operative time (minutes)	185 (57, 372)	180 (91, 372)	189 (57, 362)	0.217
Status of resection margins				0.619
R0	250 (99%)	123 (98%)	127 (99%)	
R1	3 (1.2%)	2 (1.6%)	1 (0.8%)	
Distance of closest margin (cm)	1.2 (0, 7.0)	1.2 (0, 3.6)	1.2 (0, 7.0)	0.371
Additional margin resection	29 (11%)	12 (9.6%)	17 (13%)	0.431
Post-operative outcomes	Overall N=244*	3DR N=124*	Control N=120*	p-value
Hospital length of stay (days)	2 (1, 58)	2 (1, 21)	2 (1, 58)	0.821
Chest tube duration (days)	1 (1, 36)	1 (1, 36)	2 (1, 18)	0.164
Presence of air-leak	67 (28%)	29 (24%)	38 (32%)	0.196
Duration of air leak (days)	0 (0, 21)	0 (0, 21)	0 (1, 15)	0.210
Chest tube on discharge	2 (0.8%)	1 (0.8%)	1 (0.8%)	>0.999
Home oxygen on discharge	6 (2.5%)	0	6 (5.0%)	0.013
Reintubation	1 (0.4%)	0	1 (0.8%)	0.492
Presence of any in-hospital complications	40 (16%)	12 (9.7%)	28 (23%)	0.005
Multivariable Logistic Regression Model (In-hospital Complications)				
Clinical variables	OR (95% CI)		p-value	
Presence of other comorbidities (vs absence)	2.08 (1.00-4.31)		0.051	
3DR (vs Control)	0.42 (0.20-0.89)		0.023	

* Median (Range); n (%)

CI: confidence interval; OR: odds ratio