5)

Surgery for T4 Lung Cancer

Ryosuke Tsuchiya, M.D.
Director
National Cancer Center Hospital, Tokyo, Japan

Stage I and II lung cancers are considered as the most accurate indication for surgery because 5-year survival rate after surgery of lung cancer of these two stages are over or close to 50%. 5-year survival rate of stage III and IV are less than 20-30%, therefore, lung cancers of these stages are considered as contraindication for surgery in general. However, there is no radical therapy for those advanced lung cancers except surgery. Complete resection is essential to cure the patients with locally advanced lung cancer. According to such a status of lung cancer therapy, surgery for T4 lung cancer is a good candidate to be tried as clinical study of lung cancer treatment.

Most of the T4 lung cancers are not candidate for surgery in practice. Dominic Grunenwald proposed new classification of T4 definition. He divided T4 into three categories as T4a, T4b and T4c. T4a is candidate for surgery, T4b is candidate for induction therapy followed by surgery and T4c is not candidate for surgery.

The results of surgery for T4 lung cancer will be discussed and technique of combined resection of heart, great vessels, vertebra or tracheal carina by video.

6)

Advancement of Surgical for Lung Cancer in Japan: Past, Present and Future

Ryosuke Tsuchiya, M.D.
Director
National Cancer Center Hospital Japan

Surgery for lung cancer was introduced into Japan in early 1930s, but we had to wait until 1950s surgical research for lung cancer became popular in major university hospitals. Surgery for lung cancer became a daily practice in 1970s for major university hospitals, general hospitals and sanatorium for patients with tuberculosis. Naruke, T introduced radical peumonectomy and radical lobectomy proposed by WG Cahan into Japan with his original lymph node map which is well known as "Naruke Map". A quarter century later, Asamura H proposed lobe specific lymph node dissection for T1 lung cancer according to the results of systematic lymph node dissection performed by surgeons of Naruke's generation. Naruke T and Watanabe Y also introduced broncho-plastic procedure into lung cancer surgery. Extended surgery for lung cancer invading heart, great vessels, vertebra, and/or esophagus was aggressively tried in 1980s.

After introduction of CT screening for early detection of lung cancer by Masahiro Kanko and his colleagues in early 1990s, numerous tiny lung cancers less than 2cm to 3cm in diameter were detected beyond our expectations in Japan. Tsubota N introduced "Extended Segmentectomy" to surgery for those tiny lung cancers. Okada M refined "Extended Segmentectomy" into "Radical Segmentectomy" for selected tiny lung cancers with diameter less than 2 cm.

To perform accurate anatomical segmentectoy and/or correct lymph node dissection, "Navigation Surgery" will be a key technology for future lung cancer surgery.

14th PATACSI ANNUAL CONVENTION and POSTGRADUATE COURSE
"New Frontiers in Thoracic, Cardiac and Vascular Surgery"
03-04 December 2007 / Kamia Room, EDSA Shangri-La Hotel, Mandaluyong City

Day 1 – December 03, 2007 (Monday)

9:00-10:00	Registration	
9:30-9:35	National Anthem	JOFEL I. ISIDRO, M.D.
9:36-9:40	Invocation	REYNALDO S. ESPINO, M.D.
9:41- 10:00	Welcome Remarks	CHRISTOPHER C. CHENG, M.D.
10:00- 10:10	Introduction to EMG Lecturer	NAPOLEON Y. DE GUZMAN, M.D.
10:11-10:40	ENRIQUE GARCIA MEMORIAL LECTURE	BRIG. GEN. RAFAEL REGINO, M.D.
SESSION I	**MISCELLANEOUS CARDIOVASCULAR PROCEDURES** **Chairman:** EDUARDO R. BAUTISTA, MD **Co-Chairman:** ROMEO NELSON C. LEE, MD	
10:40- 11:00	Maze Procedure	RICHARD S. NICOLAS, MD
11:00- 11:20	Local Experience in Endosaphenous Vein Harvesting	ADRIAN MANAPAT, MD
11: 20- 11:40	OPEN FORUM	
11:40- 1:00 PM	**LUNCH BREAK**	
SESSION II.	**PEDIATRIC and ADULT CONGENITAL CARDIAC and THORACIC DISEASE** **Chairman:** JOSE C. GONZALES, MD **Co-Chairman:** FRANCISCO PERALTA, MD	
1:00- 1:20	Pediatric Pleural Diseases	MILAGROS BAUTISTA, MD
1:20-1:40	Surgical Management of Thoracic Conditions in the Pediatric Age Group	ANTONIO B. RAMOS, MD
1:40- 2:00	Surgical Management for Tetralogy of Fallot	JAIME S. NUEVO, MD
2:00-2:20	A Physiologic Approach to Understanding Congenital Heart Diseases	FLORIAN NUEVO, MD

7) 2/3

2:20- 2:40 OPEN FORUM

ISRAEL C. YASAY, M.D.
Masters of Ceremonies

Day 2 – December 04, 2007 (Tuesday)

SESSION III. VASCULAR SURGERY
Chairman: FLORANTE B. LOMIBAO, M.D.
Co-Chairman: PIO V. PURINO JR, M.D.

9:30- 9:50 New Diagnostic Methods in Vascular Diseases
ORLANDO IGNACIO, MD

9:50- 10:10 Aortic Dissection: Management Strategies
AQUILEO C. RICO, M.D.

10:10- 10:30 Controversies in Thoracoabdominal Aortic Aneurysm Surgery
MARTIN ANTHONY VILLA, M.D.

10:30- 11:00 Vascular Disease Challenges
MA. TERESA ABOLA, M.D.

11:00-11:20 OPEN FORUM

11:20-2:00 ANNUAL BUSINESS MEETING

SESSION IV. TRENDS IN THORACIC SURGERY
Chairman: JOSE LUIS J. DANGUILAN, M.D.
Co-Chairman: JUN PAUL D. CASTOLO, M.D.

2:00- 2:20 Decision Making on Management of End-stage Lung failure
LUCIO UY, M.D.

2:20- 2:40 Early Detection with CT Screening for Lung Cancer
RYOSUKE TSUCHIYA, MD

7) 3/3

2:40- 3:00 Combined Resection for Lung Cancer with Superior Vena Cava Involvement

RYOSUKE TSUCHIYA, MD

3:00-3:20 OPEN FORUM

JOSEPH J. BAUTISTA, M.D.
Masters of Ceremonies

5:00-8:00 Fellowship Night (Garden Ballroom 1 & 2)

HON. MAYOR ALFREDO S. LIM
Inducting Officer

SAMUEL T. ANDIN, M.D.
Masters of Ceremonies

1．がん対策基本法と放射線治療

国立がんセンター中央病院　病院長
土屋　了介 先生

がん対策基本法が平成18年6月23日に公布され、平成19年4月1日に施行されました。基本法の理念に従って国が平成19年12月に閣議決定した「がん対策推進基本計画」を基に、都道府県は「がん対策推進計画」を本年3月までに作成することになっています。

がん対策というと従来は研究が重んじられましたが、基本法には基本的施策として、

① がんの予防及び早期発見の推進
② がん医療の均てん化の促進等
③ 研究の推進等

が挙げられています。研究の推進の前に予防・早期発見・医療が挙げられたことは画期的なことと言えます。

がんの予防及び早期発見の推進では「がん予防の推進」と「がん検診の質の向上等」が挙げられ、がん医療の均てん化の促進等では「専門的な知識及び技能を有する医師その他の医療従事者の育成」、「医療機関の整備等」、「がん患者の療養生活の質の維持向上」と「がん医療に関する情報の収集提供体制の整備等」が挙げられました。「国及び地方公共団体は、がん患者がその居住する地域にかかわらず等しくそのがんの状態に応じた適切ながん医療を受けることができるよう、専門的ながん医療の提供等を行う医療機関の整備を図るために必要な施策を講ずるものとする」とされ、「医療機関等の間における連携協力体制の整備を図るために必要な施策を講ずるものとする」と記載されている。そのために、「手術、放射線療法、化学療法その他のがん医療に携わる専門的な知識及び技能を有する医師その他の医療従事者の育成を図るために必要な施策を講ずるものとする」と記載された。

基本法の施行を受けて作成された「がん対策推進基本計画」では、重点的に取り組むべき課題

① 放射線療法および化学療法の推進並びにこれらを専門的に行う医師等の育成
② 治療の初期段階からの緩和ケアの実施
③ がん登録の推進

が挙げられています。

すなわち、従来、我が国では治療の主体が外科であったことの反省から、放射線療法・化学療法・緩和医療を重点的に取り組んでいく必要があることが指摘されています。今回の講演では、現状へ至る経緯と、今後の取り組みにおける課題について、参加される皆さんと一緒に考えたいと存じます。

The Association of Japanese Thoracic Surgeons

Ryosuke Tsuchiya M.D.
土屋 了介
Director
National Cancer Center Hospital

明治維新 Meiji Restoration in 1858

- Before Meiji Restoration (明治維新)
  - Japan learned everything from China (中國)
- After Meiji Restoration (明治維新)
  - accepted Western Culture (歐州・美國)

明治維新 Meiji Restoration in 1858

- Before Meiji Restoration
  - 漢方：東洋醫學＝中國醫學
- After Meiji Restoration
  - German Medicine
- After World War II
  - American Medicine

日本醫學會

- Japanese Association of Medical Sciences
- 1902 日本聯合醫學會
- 1910 日本醫學會

Japanese Medical Associations

- Japanese Association of Medical Sciences
  - 日本醫學會 1902
- Japanese Society of Internal Medicine
  - 日本内科學會 1903
- Japan Surgical Society
  - 日本外科學會 1899
- Japanese Association for Thoracic Surgery
  - 日本胸部外科學會 1948
- Japanese Association for Chest Surgery
  - 日本呼吸器外科學會 1984

Major Associations (Thracic Surgeons)

- Japan Surgical Society
  - 日本外科學會 1899

<u>49years</u>
- Japanese Association for Thoracic Surgery
  - 日本胸部外科學會 1948

<u>36yers</u>
- Japanese Association for Chest Surgery
  - 日本呼吸器外科學會 1984

<u>23yers</u>
- Present

Associations for TS (Thoracic Surgeons)

1. Japanese Association for Chest Surgery 1984 4,000人
   http://www.jacsurg.gr.jp/ 日本呼吸器外科学会
2. Japanese Association for Thoracic Surgery 1948 8,000人
   http://www.jpats.org/ 日本胸部外科学会
3. Japan Lung Cancer Society 1960 8,000人
   http://www.haigan.gr.jp/ 日本肺癌学会
4. Society for Respiratory Endoscopy 1978 5,182人
   http://www.isre.org/ 日本呼吸器内視鏡学会
4. Japan Surgical Society 1899 37,884人
   http://www.issoc.or.jp/journal/surgerytoday/index.html
   日本外科学会
6. Japan Society for Endoscopic Surgery 1988 8,000人
   http://www.asas.or.jp/jses/ 日本内視鏡外科学会
7. Japanese Respiratory Society 1961 10,224人
   http://www.jrs.or.jp/ 日本呼吸器学会

2007/1/21 第一屆 中國胸科外科論議 土屋 了介 7/35

American Associations for TS

1. Society of Thoracic Surgeons
   STS 4,000
   - General Thoracic Surgeons
   - Cardiovascular Surgeons
2. American Association of Thoracic Surgery
   AATS 4,000
   - General Thoracic Surgeons
   - Cardiovascular Surgeons

2007/1/21 第一屆 中國胸科外科論議 土屋 了介 8/35

Japanese Associations for TS

1. Japanese Association for Chest Surgery
   - General Thoracic Surgeons (Lung & Mediastinum)
2. Japanese Association for Thoracic Surgery
   - Cardiovascular Surgeons
   - General Thoracic Surgeons (Lung & Mediastinum)
   - Esophageal Surgeons
3. Japanese Association for Esophagus
   - Esophageal Surgeons

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Education System: Program

- ☐ Respiratory Surgeon
  - ☐ Joint Committee
    - ■ Jap Ass for Chest Surgery
    - ■ Jap Ass for Thoracic Surgery
- ☐ Cardio-vascular Surgeon
  - ☐ Joint Committee
    - ■ Jap Ass for Thoracic Surgery
    - ■ Jap Ass for Cardio-vascular Surgery
    - ■ Jap Ass for Vascular Surgery
- ☐ Esophageal Surgeons
  - ☐ Jap Society for Gastro-Enterological Surgery

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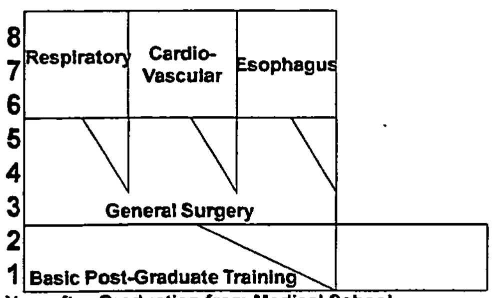
Program



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Requirement for Title of Res Surg

- ☐ 50 operations
  - ■ 30 Open Thoracotomy
  - ■ 20 VATS
  - ■ 20 Mediastinal Dissection
  - ■ 5 Broncho-plastic Procedure

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Instructors, Specialists

☐Instructors	487
☐Specialists	1,138

Lung Cancer 肺癌

- ☐Lung Cancer Patients 肺癌 — 60,000/year
- ☐Rate of Surgery — 50%
- ☐Lung Cancer Surgery 手術 — 30,000/year

Lung Cancer Surgery

☐Surgery 手術	30,000
☐Surgery per Surgeon	100
☐No. of Specialists 専門醫	300
☐Working Period	35 歳－55 歳
☐Newcomer 新専門醫	15

General Thoracic Surgical Club

- **General Thoracic Surgeons**
  - ☐ Lung Cancer + benign
  - ☐ Esophageal Cancer + benign
- **300 American Members**
- **50 International Members**

Japan vs. China

☐Population 人口

■ Japan 日本	120,000,000
■ China 中國	1,300,000,000

☐Lung Cancer Surgeons

■ Japan 日本	300
■ China 中國	3,000

Mission of Association 服務

- Practice 臨床
  - Contribution to Community
    - Information
- Education 教育
- Research 研究
  - Advancement of Thoracic Surgery

JJCLCR 肺癌聯合登録委員会

Japanese Joint Committee of Lung Cancer Registry

- The Japanese Association for **Chest Surgery**
- The Japan **Lung Cancer** Society
- The Japanese **Respiratory** Society

A Japanese Lung Cancer Registry Study

REGISTRY:

- Surgically resected primary lung neoplasms only in 1994 from 303 teaching hospitals in Japan
- Neoplasms including lung cancer of all histologic types and low-grade malignancy
- Exclusion of exploration case and recurrent tumor
- A retrospective questionnaire on 27 items

A Japanese Lung Cancer Registry Study

7,488 pts. registered from 303 teaching hospitals

→ 15 ineligible reports

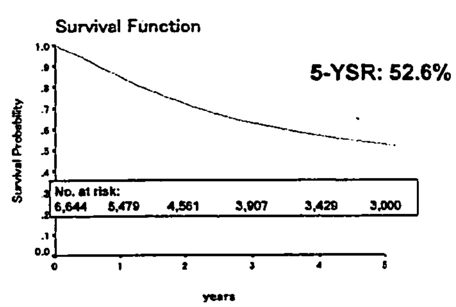
→ 749 histologies of SCLC or low-grade malignancy

6,644 pts. with non-small cell histology (89.9%) for this analysis

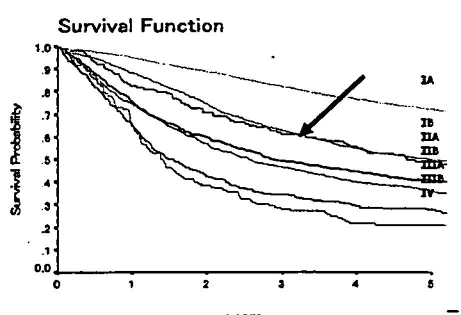
Rare Histological Type

□Small cell carcinoma	248
□Carcinoid	73
□Adenoid cystic carcinoma	4
□Mucoepidermoid carcinoma	19

OVERALL SURVIVAL 6,644 NSCLC



SURVIVAL by c-STAGE



DIFFERENCE between STAGES:
c-STAGE

c-Stage	n	5-YSR(%)	Difference (P)
IA	2,423	72.1	
IB	1,542	49.9	0.0000
IIA	150	48.7	0.4969
IIB	746	40.6	0.0458
IIIA	1,270	35.8	0.0439
IIIB	366	28.0	0.0000
IV	147	20.8	0.1577

2007/1/21

Lung Cancer (2005) 50:227-234

Prognosis of 6644 resected non-small cell lung cancers in Japan: A Japanese lung cancer registry study

The Japanese Joint Committee of Lung Cancer Registry

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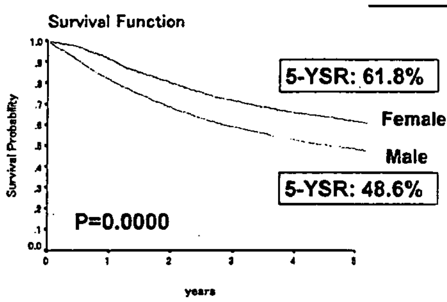
SURVIVAL CURVES BY GENDER



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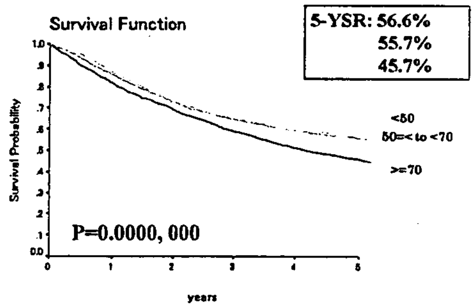
SURVIVAL CURVES BY AGE



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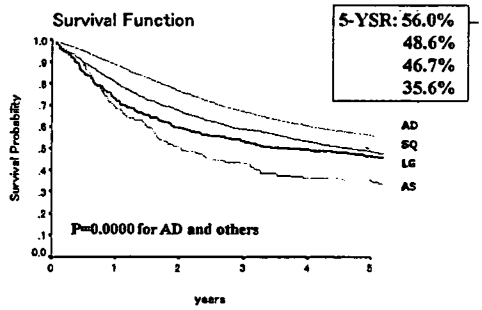
SURVIVAL CURVES BY HISTOLOGY



2007/1/21

IASLC Staging Project
NSCLC and SCLC Cases 2 JUN 2004

	Total	Included	Primary Reason Excluded			
			Time Frame	Surv -Data	Stage	Total
Total	48,445	43,455	523	591	3,876	4,990
Japan	7,256	7,143	6	99	8	113
Korea	1,084	840	244	0	0	244
MacCallum	203	183	20	0	0	20
U Sydney	2,546	1,609	0	0	3	937
Amsterdam	13,895	11,346	0	0	2,549	2,549
ELCWP	2,068	2,067	0	1	0	1
Flemish	6,769	5,189	0	442	1,129	1,571
Gdansk	1,262	1,247	0	2	13	15
Grenoble	906	692	178	3	33	214

(table continues next slide)

2007/1/21

IASLC Staging Project

NSCLC and SCLC Cases

21 JUN 2004

	Total	Included	Primary Reason Excluded			
			Time Frame	Surv Data	Stage	Total
Heidelberg	5,391	5,391	0	0	0	0
Jules Bordet	746	697	5	23	21	49
Perugia	110	94	5	3	8	16
Spain	2,991	2,941	0	18	32	50
Torino	1,006	918	65	0	23	88
NCIC	255	255	0	0	0	0
SWOG/BLOT	2,900	2,843	0	0	57	57
Total	48,445	43,455	523	591	3,876	4,990

(table continued from previous slide)

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IASLC Staging Project

Clinical Stage – NSCLC (Broad Inclusion Criteria)

	Total	0	1A	1B	2A	2B	3A	3B	4
Total	31580	24	4348	5726	249	2730	4960	5168	8375
Japan	6875	11	2499	1691	141	800	1293	384	156
MacCallum	183	0	8	22	3	19	78	53	0
Amsterdam	8500	0	713	1194	30	395	1111	1728	3329
ELCWP	1489	0	14	5	1	63	340	281	785
Flemish	4699	3	374	871	37	365	826	907	1316
Grenoble	178	0	31	59	3	19	34	23	9
Heidelberg	4460	0	193	489	30	545	946	1215	1062
Jules Bordet	550	0	10	31	0	14	60	97	338
Spain	2570	10	506	1423	0	364	90	137	40
NCIC	35	0	0	0	0	0	35	0	0
SWOG/BLOT	2041	0	0	61	4	146	147	343	1340

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IASLC Staging Project - NSCLC Database Nodal station

	cTNM	pTNM	Size of lesion	T-descriptors (cT or pT)	Completeness of Resection	Nodal Stations	T4 Subset (cT or pT)	
							Malignant effusions (+/-)	Satellite Nodules (+/-)
Total	31,490	20,622	11,314	16,657	14,270	8,144	3,043	1456
Japan	6,875	6,753	6,857	6,899	6,744	6,899	768	816
Korea		831	778					120
MacCallum	183		138					
U Sydney		1,591		1,591			172	
Amsterdam	8,500	2,268						
ELCWP	1,489						132	
Flemish	4,699	1,419		4,731	1,374		1,133	
Gdansk	1	1239						
Grenoble	178	648						
Heidelberg	4,460	2,060			2,060			
Jules Bordet	550	11					102*	
Perugia		94	91					
Spain	2,570	2,689	2,558	2,890	2,876		458	458
Torino		895	892	177	894	895	6	26
NCIC	35					35		
SWOG/BLOT	1951	124		362	322	315	200	35

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3 Poles in the World

- Europe
- America
- Asia
  - China
  - Japan
  - Korea

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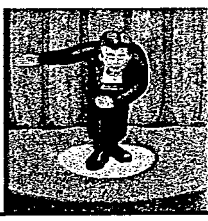
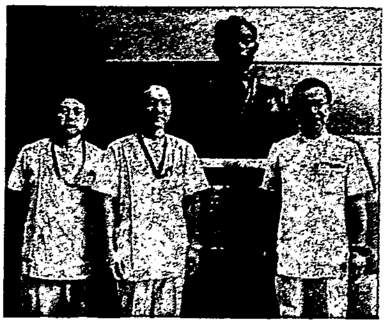
謝 謝



2007/1/21　35/35

Sentinel node navigation segmentectomy for clinical stage IA non–small cell lung cancer

Hiroaki Nomori, MD, PhD,[a] Koei Ikeda, MD, PhD,[a] Takeshi Mori, MD,[a] Hironori Kobayashi, MD,[a] Kazunori Iwatani, MD,[a] Koichi Kawanaka, MD, PhD,[b] Shinya Shiraishi, MD, PhD,[b] and Toshiaki Kobayashi, MD, PhD[c]



From right to left: Drs Nomori, Mori, and Ikeda. The Bronze statue is Dr Shibasaburo Kitasato

Objective: Intraoperative frozen section examination of sentinel lymph nodes was conducted to determine the final indication for segmentectomy for clinical T1 N0 M0 non–small cell lung cancer.

Methods: Between April 2005 and July 2006, 52 patients with clinical T1 N0 M0 non–small cell lung cancer were prospectively treated by segmentectomy with sentinel node identification. The day before surgery, technetium-99m tin colloid was injected into the peritumoral region. After segmentectomy and lymph node dissection, sentinel nodes identified by measuring radioactive tracer uptake were examined for intraoperative frozen sections, which were serially cut 2 to 3 mm in thickness. When sentinel node metastasis was observed, segmentectomy was converted to lobectomy.

Results: Sentinel nodes were identified in 43 (83%) patients. The average number of sentinel nodes was 1.6 ± 0.9 (range: 1–5) per patient. Of 3 patients with metastatic sentinel lymph nodes, 2 underwent lobectomy and 1 larger segmentectomy. None of the other 40 patients had metastatic sentinel lymph nodes and therefore they were treated with segmentectomy. Pathologic staging with permanent sections was N0 in all of the 40 patients. On the other hand, in 9 patients whose sentinel nodes could not be identified, intraoperative frozen sections were required for 5.4 ± 2.3 lymph nodes, which was significantly more than 1.6 ± 0.9 in the 43 patients with sentinel node identification ($P < .001$).

Conclusion: Sentinel node identification is useful to determine the final indication of segmentectomy for clinical T1 N0 M0 non–small cell lung cancer by targeting the lymph nodes needed for intraoperative frozen section diagnosis.

From the Departments of Thoracic Surgery[a] and Radiology,[b] Graduate School of Medical Sciences, Kumamoto University, Honjo, Kumamoto, Japan; and the Department of Assistive Diagnostic Technology,[c] National Cancer Center Hospital, Tokyo, Japan.

This work was supported, in part, by Grant-in-Aid from the Ministry of Health, Labor, and Welfare, Japan.

Received for publication Aug 20, 2006; revisions received Oct 7, 2006; accepted for publication Oct 23, 2006.

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J Thorac Cardiovasc Surg 2007;133:780-5

0022-5223/$32.00

doi:10.1016/j.jtcvs.2006.10.027

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In 1995, the Lung Cancer Study Group[1] conducted a prospective randomized controlled trial of limited resection versus lobectomy for clinical T1 N0 M0 non–small cell lung cancer (NSCLC) and concluded that the former was inferior to the latter regarding local recurrence and survival. However, the limited resection group in the study included both segmentectomy and wedge resection, and the curability for T1 N0 M0 NSCLC differed between the two procedures. On the other hand, there have been several reports describing that survivals were similar between patients treated with segmentectomy and those with lobectomy.[2-7]

The most important issue regarding segmentectomy versus lobectomy is whether postoperative local recurrence is increased. Whereas Warren and Faber[8] reported local recurrence in 15 (22.7%) of 66 patients after segmentectomy versus 5 (4.9%) of 103 patients after lobectomy, other authors reported that local recurrence after segmentectomy with complete dissection of hilar and mediastinal lymph nodes was equal to that after lobectomy.[3-6] However, for determining the final indication for segmentectomy, intraoperative frozen sections must be examined for all of the hilar

Abbreviations and Acronyms

CT	= computed tomography
FDG-PET	= fluorodeoxyglucose–positron emission tomography
NSCLC	= non–small cell lung cancer
SN	= sentinel node
SPECT	= single photon emission computed tomography

and lobe-specific mediastinal lymph nodes to confirm the intraoperative N staging to be N0.[3-6]

A sentinel node (SN) is defined as the first lymph node within the lymphatic basin reached by lymph draining from the primary lesion. Recently, SNs have been identified by a radioactive tracer with or without dye during surgery for melanoma, breast cancer, gastrointestinal cancer, and lung cancer to reduce lymph node dissection.[9-14] We[13,14] previously reported that SN identification with technetium-99m tin colloid could establish the first site of nodal metastasis in NSCLC.

In the present study, we used SN identification to target the lymph nodes submitted for intraoperative frozen section diagnosis, which might determine the indication of segmentectomy. In addition, unlike Tsubota,[3] Okada,[4] Yoshikawa,[5] and their associates, who proposed that the indication for segmentectomy was T1 N0 M0 NSCLC less than 2 cm in size, we proposed that it was T1 N0 M0 NSCLC without size limitation. Because SN identification served as the final indication of segmentectomy, we named the procedure "sentinel node navigation segmentectomy."

Patients and Methods

Eligibility

The study protocol for SN navigation segmentectomy was approved by the Ethics Committee of Kumamoto University Hospital in March 2005. Informed consent was obtained from all patients after discussing the risks and benefits of the proposed surgery with their surgeons.

Patients

Between April 2005 and July 2006, 103 patients with NSCLC underwent surgical treatment. Of these, 73 patients had stage c-T1 N0 M0 cancer according to the findings of both computed tomography (CT) and fluorodeoxyglucose–positron emission tomography (FDG-PET). SN navigation segmentectomy was prospectively performed when (1) c-T1 N0 M0 NSCLC was identified in the peripheral lung; (2) the tumor on CT was more than 2 cm away from the pulmonary vein running at the boundary of the affected segment; (3) intraoperative frozen sections of SN showed no metastasis; (4) the surgical margin was intraoperatively found to be more than 2 cm from the tumor; and (5) tumors located centrally within the inner one third of the lung or in the right middle lobe were excluded. The stage of disease was based on the TNM classification of the International Union Against Cancer.[15] The lymph node nomenclature used was according to the lymph node map of Naruke and associates,[16] which was approved by the Japan Lung Cancer Society (Table 1).

TABLE 1. Lymph node nomenclature

N2 node	N1 node
Superior mediastinal	Hilar
No. 1. Highest mediastinal	No. 10. Hilar
No. 2. Paratracheal	No. 11. Interlobar
No. 3. Pretracheal	No. 12. Lobar
No. 4. Tracheobronchial	
Aortic	Intrapulmonary
No. 5. Botallo	No. 13. Segmental
No. 6. Para-aortic	No. 14. Subsegmental
Inferior mediastinal	
No. 7. Subcarinal	
No. 8. Paraesophageal	
No. 9. Pulmonary ligament	

Administration of Radioactive Colloid

The day before surgery, a 23-gauge needle was introduced into the peritumoral region under single photon emission computed tomography/computed tomography (SPECT/CT) system guidance, which incorporates a gantry-free SPECT with dual-head detectors (Skylight; ADAC Laboratories, Milpitas, Calif) and an 8 multidetector CT scanner (Light-Speed Ultra; General Electrics, Milwaukee, Wis). Technetium tin colloid (6−8 mCi) suspended in a 1- to 1.5-mL volume was injected in a single shot. SPECT/CT was performed 5 minutes after the injection and the next morning just before the operation.

SN Identification

The radioactivity of the resected lymph nodes was counted with a handheld gamma probe (Navigator; Auto Suture Japan, Tokyo, Japan). The radioactivity was measured for a 10-second period. SN was defined as any node for which the count was more than 5 times the radioactivity of the resected tissue with the lowest count.

SN Navigation Segmentectomy

Under thoracotomy, SN navigation segmentectomy was performed as follows: (1) Pulmonary arteries and bronchi of the affected segments were cut at the hilum; (2) pulmonary veins along the boundary of segments were isolated from the center to periphery; (3) the affected segments along the pulmonary veins were resected with staplers; (4) the hilar and systematic mediastinal lymph nodes were dissected; (5) the radioactivity of dissected lymph nodes was counted for SN identification; (6) SNs were examined by intraoperative frozen sections, which were serially cut 2 to 3 mm in thickness; (7) if the intraoperative frozen sections of the SN showed no metastasis, the operation was completed with segmentectomy; (8) if the sections of the SN showed metastasis, lobectomy was performed; and (9) if the SN could not be identified because radioactivity of the lymph nodes was low, all of the hilar and lobe-specific mediastinal lymph nodes were submitted for

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TABLE 2. Sites of segmentectomy

Segment	No. of patients	Segment	No. of patients
Right		Left	
Upper lobe		Upper lobe	
S1	3	S1 + 2	4
S2	2	S3	2
S1 + S2	2	S1 + 2 + 3	9
S3	2	S4 + 5	7
S3 + S2b	1		
S2 + S3a	1		
Lower lobe		Lower lobe	
S6	4	S6	3
S7 + 8	1	S8	1
S8	1	S8 + 9	2
S9 + S10	2	S9 + 10	1
S7–10	1	S10	1
S6 + S9 + S10	1	S8–10	1
Total	21		31

Right upper lobe: *S1*, apical; *S2*, anterior; *S3*, posterior. Right lower lobe: *S6*, apical; *S7*, medial; *S8*, anterior; *S9*, lateral; *S10*, posterior. Left upper lobe: *S1+2*, apical posterior; *S3*, apical anterior; *S4*, superior lingular; *S5*, inferior lingular. Left lower lobe: *S6*, apical; *S8*, anterior; *S9*, lateral; *S10*, posterior.

TABLE 3. Characteristics of patients with and without sentinel node identification

	Sentinel lymph node	
	Identifiable	Nonidentifiable
Mean age (y)	69 ± 7	71 ± 7
Sex		
Male	26	8
Female	17	1
Mean tumor size (cm)	1.9 ± 0.7	2.1 ± 0.7
Histologic type		
Adenocarcinoma	37	6
Squamous cell carcinoma	4	2
Adenosquamous carcinoma	2	1
No. of lymph nodes submitted for intraoperative frozen diagnosis	1.6 ± 0.9	5.4 ± 2.3*
Pathologic TNM		
T1 N0 M0	39	9
T2 N0 M0	1	0
T1 N1 M0	1	0
T2 N1 M0	1	0
T1 N2 M0	1	0
Total	43	9

*$P < .001$.

intraoperative frozen section. Lobe-specific lymph nodes were defined as follows: No. 3 and No. 4 for the right upper lobe, No. 5 for the left upper lobe, and No. 7 for the lower lobe of both sides.[17]

Primary End Points of the Study

Primary end points of the study are as follows: (1) Can SN identification diagnose pathologic N stage during segmentectomy? (2) Are the survival and local recurrence after SN navigation segmentectomy similar to those after lobectomy?

Statistical Analysis

All data were analyzed for significance by the 2-tailed Student *t* tests. All values in the text and tables are given as mean ± SD.

Results

Operative procedures for the 73 patients with c-T1 N0 M0 were lobectomy in 12 patients, segmentectomy in 52, and wedge resection in 9. The reasons for conducting lobectomy in the 12 patients were as follows: (1) tumors in the right middle lobe in 5 patients; (2) tumors located centrally in 5 patients; (3) multiple lesions in the same lobe in 1 patient; and (4) thoracoscopic lobectomy as requested by the patient. As a result, 52 patients were consecutively enrolled for SN navigation segmentectomy. Table 2 shows the sites of segmentectomy for the 52 patients. The average number of dissected lymph node stations and lymph nodes per patient was 6 ± 1.8 stations and 12.5 ± 5.9 lymph nodes, respectively. Among the 52 patients, SNs could be identified in 43 (83%). The time needed for SN identification was within 5 minutes in each patient. The characteristics of the 43 patients with SN identification and of the 9 patients without are shown in Table 3. Average tumor size on CT was 1.9 ± 0.7 cm (range: 0.8–3.0 cm) and 2.1 ± 0.7 cm (range: 1.4–3.0 cm) in the patients with and without SN identification, respectively. Seventeen (40%) of the 43 patients with SN identification and 4 (44%) of 9 patients without had tumors larger than 2 cm. Pathologic tumor stages in the 43 patients with SN identification were T1 N0 M0 in 39, T2 N0 M0 in 1, T1 N1 M0 in 1, T2 N1 M0 in 1, and T1 N2 M0 in 1, whereas the stage in all 9 patients without SN identification was p-T1 N0 M0. The tumors in 2 patients were pathologically classified as T2; one tumor was spread over the pleura and the other was more than 3 cm in size in the permanent section. The average number of lymph nodes submitted for intraoperative frozen section examination was significantly less in the 43 patients with SN identification (1.6 ± 0.9 [range: 1–5] per patient) than in the 9 patients without SN identification (5.4 ± 2.3 [range: 3–10] per patient) ($P < .001$).

Table 4 shows the SN identified in the hilar lymph node stations. The number of stations having SN increased in numeric order from No. 10 to 13 stations. In the mediastinal lymph node stations, the SN was identified in 15 of the 43 patients (35%). Eleven of the 15 patients had SNs in both the hilar and mediastinal lymph node stations, whereas the remaining 4 patients had SNs only in the mediastinum. The distribution of mediastinal SNs is shown in Table 5, which

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TABLE 4. Sentinel lymph node mapping in the hilar lymph node stations

	Sentinel nodes	
Station	No. of patients	Percent
10	7/3	16.3
11	7/43	16.3
12	12/43	27.9
13	22/43	51.2

TABLE 5. Sentinel nodes at the mediastinum in each lobe

Tumor location	Station of mediastinal SN	No. of patients	Percent
RUL	3 or 4	3/10	30.0
RLL	3 or 4	2/9	22.2
	7 and 3	1/9	11.2
LUL	5	8/18	44.4
LLL	7	2/6	33.3

SN, Sentinel node; *RUL*, right upper lobe; *RLL*, right lower lobe; *LUL*, left upper lobe; *LLL*, left lower lobe.

was lobe-specific; that is, 3 of the 10 patients with primary tumor in the right upper lobe had SN in No. 3 or 4 stations; 3 of the 9 patients with primary tumor in the right lower lobe had SN in No. 7, 3, or 4 stations; 8 of the 18 patients with primary tumor in the left upper lobe had SN in No. 5 station; and 2 of the 6 patients with primary tumor in the left lower lobe had SN in No. 7 station.

In 3 (7%) of the 43 patients with SN identification, metastasis was found in the SN by intraoperative frozen section (Table 6). For 2 of the 3 patients (patients 1 and 2), operative procedures were converted to lobectomy. The operative procedure for the remaining patient (patient 3) was converted from posterior apical segmentectomy to larger segmentectomy (upper division segmentectomy, but not to upper lobectomy), because of his age (80 years old). Pathologic N stages were N1 in 2 patients and N2 in 1 patient. Although both patients 1 and 2 had metastasis only in the SN, patient 3 had metastasis in both SN (No. 5) and non-SN (Nos. 12 and 13). Tumors in all of the other 40 patients were classified as p-N0 by permanent sections.

There were no complications associated with radioisotope injection necessitating tube drainage, such as bleeding or severe pneumothorax. One patient had empyema 3 days after segmentectomy, which was cured by drainage and antibiotics on the 23rd postoperative day. There were no the other major complications associated with segmentectomy, including prolonged air leakage of more than 5 days. The postoperative follow-up was performed by chest and abdominal CT and brain magnetic resonance imaging every 3 months after the operation. No patients were lost to follow-up. The mean follow-up period after surgery in the 52 patients was 8 months (range: 1–15 months). Postoperative recurrence occurred in 1 patient, who underwent an apical segmentectomy of the right lower lobe for adenosquamous carcinoma 2.9 cm in size. The recurrence was at 5 months after segmentectomy, at the extraregional lymph node for tumor in the right lower lobe, that is, at the interlobar lymph node (No. 11) between the right upper lobe and middle lobe, and treated by completion pneumonectomy. During the segmentectomy of this patient, No. 13 and No. 4 were identified as SNs, which showed no metastasis in intraoperative frozen sections. The patient is now alive 11 months after the completion pneumonectomy without recurrence. The other 51 patients are also now alive without recurrence.

Discussion

The present study shows that the SN navigation segmentectomy using radioisotope tracers could increase the accuracy of intraoperative N staging and could serve as the final indication for segmentectomy. In the 3 patients with N1 or N2 disease, intraoperative frozen sections of SNs showed metastasis, which suggested the need for lobectomy. In 9 segmentectomy-treated patients whose SNs could not be identified, all hilar and lobe-specific lymph nodes were required for diagnosis, a significantly larger number than in the 43 patients whose SNs could be identified. SN identification therefore could determine a final indication for segmentectomy by targeting the lymph nodes needed for intraoperative frozen section diagnosis. In addition, serial sections of SNs during surgery might find micrometastasis more easily than single section in each of a larger number of lymph nodes.

Although the postoperative follow-up period is still short, 1 patient had local recurrence 5 months after segmentectomy. The recurrence site of this patient, however, was the extraregional lymph node. In addition, the histologic type of this patient was adenosquamous carcinoma, which is known to have poorer prognosis than other types of NSCLC.[18,19] We therefore consider that the patients with clinical T1 N0 M0 NSCLC of high malignant grade, such as adenosquamous carcinoma, large cell neuroendocrine carcinoma, adenocarcinoma with high FDG uptake on PET, and NSCLC with high carcinoembryonic antigen serum level, would be preferably treated by lobectomy rather than segmentectomy, even if the intraoperative lymph node staging is N0.

Skip metastasis to the mediastinal lymph nodes has been reported to occur in 20% to 40% of patients with NSCLC,[17,20] which could be because some lymphatic flow from the lung goes directly to the mediastinum through the pleura and not to the hilar lymph node stations.[21] The present study showed that SNs were identified in the mediastinum in 15 (35%) of 43 patients and the lymphatic route to each mediastinal lymph node station was lobe-specific.

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TABLE 6. Patients who were converted to major lung resection

Patient No.	Age/sex	Histologic type	Planned segmentectomy	SN with metastasis	Converted procedure	Pathologic TNM
1	70/M	Ad	Apical segment of RLL	No. 13	Lobectomy	T1 N1 M0
2	72/M	Ad	Apical segment of RLL	No. 11	Lobectomy	T2 N1 M0
3	80/M	Ad	Posterior apical segment of LUL	No. 5	Upper division segmentectomy	T1 N2 M0

SN, Sentinel node; *Ad,* adenocarcinoma; *RLL,* right lower lobe; *LUL,* left upper lobe.

Therefore, to determine the intraoperative indication for segmentectomy without using SN identification, not only hilar lymph nodes but also lobe-specific mediastinal lymph nodes should be submitted for intraoperative frozen section diagnosis. The SN identification can target the lymph nodes among those.

The identification rate of SNs was 83% in the present study, as it was in the data of previous reports by several authors, that is, 63% to 82%.[12-14] We[14] previously reported the results of SN identification in 104 patients with clinical stage I NSCLC. Of the 104 patients, 15 patients had N1 or N2 disease. Although SN could be found to have metastases during the operation in 13 (87%) of those 15 patients, it produced false negative results in the remaining 2 patients. One of the 2 patients had T2 tumor and metastasis in the No. 12 nodal station, and the other had T1 tumor and metastasis in the No. 14 nodal station, which could not be identified as SN by our procedure because of its intrapulmonary location. We therefore believe that SN could be identified by our procedure in most of the patients with T1 N0 M0 NSCLC.

Although it has been reported that 20% to 25% of patients with clinical stage I disease have mediastinal lymph node metastasis,[22,23] the present study showed only 3 (6%) of 52 patients with N1 or N2 disease. Our procedure for lymph node dissection was systematic and then yielded 6 ± 1.8 nodal stations and 12.5 ± 6 lymph nodes to be dissected per patient. The low number of patients with N1 or N2 disease in the present study is probably due to the institutional setting; that is, most lung cancers in our patients were found by routine CT examination, resulting in a higher rate of early-stage NSCLC than usual.

The Lung Cancer Study Group study in 1995 (the only prospective randomized trial of lobectomy versus limited resection for T1 N0 NSCLC) reported that limited resection was inferior to lobectomy regarding death rate and local recurrence.[1] However, the study included a significant number (33%) of wedge resections in the limited resection group and did not analyze the results of segmentectomy. In addition, compared with clinical staging in 1995 when the Lung Cancer Study Group study was reported, it is now more accurate because of improved CT and FDG-PET technology. Therefore, a prospective randomized trial of lobectomy versus segmentectomy should be performed for c-T1 N0 M0 NSCLC. The SN navigation segmentectomy, which can target lymph nodes for intraoperative frozen section diagnosis, is a reasonable procedure for determining the final indication of segmentectomy.

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生体医工学
45(2): 177-184, 2007

研究

MRIによる小型受信コイルの位置姿勢計測法の開発と評価

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Tracking Method of Small Receiver Coil Using MR Scanner

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Abstract　MR guided surgery is quite effective in realizing accurate and safe minimally invasive surgery (MIS). The combination of intra-operative MRI, surgical navigation system, and surgical robot should be of practical use in the field of MIS in the future. When we use flexible endoscope type robotic manipulator, the position and the orientation of the tip point of the flexible forceps should be navigated and controlled by a robotic manipulator. However, the conventional position sensor can not be used because of the strong magnetic field and the limited workspace. We propose a novel tracking method named extended active tracking (EAT), which is based on the active tracking algorithm. EAT can measure the position and the orientation of the tracking coils synchronically. The principle of EAT is three points measurement by three series inductance. We can calculate the orientation of three coils using the measured 3-D positions of coils. In this paper, three experiments was conducted to evaluate the basic performance of the EAT. First experiment is the flip angle adjustment for the reduction of background noise, which is caused by the proton around each inductance. The experimental results shown that the inductance positions could be clearly observed without background noise at 6-deg flip angle with NMR signal peaks. Second experiment is the reproducibility evaluation. The fluctuation of measurement position and orientation were less than 0.3 mm (SD) and 1.0 deg (SD) at various positions and orientations. And standard deviation of the distance between the inductances at various positions and orientations is less than resolution (0.78 mm). Third experiment is an accuracy evaluation. The position measurement accuracy was 0.39 mm (RMS) using an optical tracking device. The orientation measurement accuracy was 3.5 deg (RMS) when the tracking coil was rotated 30 degree. Evaluation result suggests that EAT is possible to be used inside a patient body with the required accuracy.

Keywords: Intra-operative MRI, MR guidance, device tracking.

1. はじめに

低侵襲手術に対する工学的支援としてコンピュータ外科がある．代表的なアプリケーションとしては da Vinci (Intuitive Surgical Inc., California, USA) に代表される手術支援ロボットや，手術対象およびその周辺臓器等と術具の位置関係を二次元ないしは三次元のモデルで表示する手術ナビゲーションシステムなどがある．これらの利点を生かし，手術支援ロボットを術中画像誘導に用いることにより，安全かつ精密な治療が可能となる．そのなかでも，今後研究が進むと考えられるものとして，図1に示されるようなMRI下の軟性内視鏡下低侵襲手術システムが挙げられる．このシステムは術中MRI，手術ナビゲーションシステム，軟性鉗子，手術マニピュレータから構成される．術中画像誘導により患部の位置を正確に把握し，患部へのアプローチの自由度が高い軟性内視鏡型手術ロボットにより，患部に対して適切な治療を行おうとするものである[1-4]．

内視鏡下手術において，術具の位置・姿勢計測は不可欠である．特に手術ナビゲーションシステムを使用する場合はリアルタイムに術具の位置姿勢をトラッキングする必要があり，その計測結果を術前画像に重ねることで，術具と周辺臓器等との位置関係を提示する．また，手術ロボットの制御をするためにも術具先端の位置・姿勢を術中計測する必要がある．

現在，臨床の場で使用されている位置計測装置には，光を使用した光学式位置計測装置，磁場を利用した磁気式位

生体医工学シンポジウム2006発表（2006年，新潟）
2006年7月26日受付，2006年11月9日改訂，2006年12月7日再改訂，2007年1月11日再々改訂
Received July 26, 2006; revised November 9, 2006, January 11, 2007.
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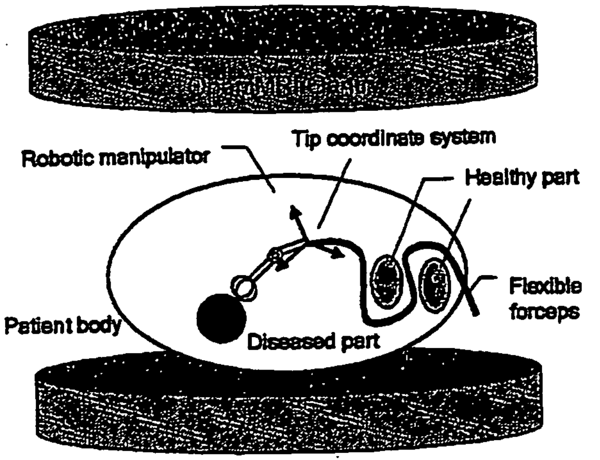

図1 オープンMRI下における軟性鉗子による低侵襲手術システムの構想
Fig. 1 System configuration of open-MRI guided minimally invasive surgery with flexible instruments.

置計測装置などがある．またMRI下に限定したものには傾斜磁場による位置計測法がある．これらの中で，MRI下で使用可能であるのは光学式および傾斜磁場方式である．光学式はケーブル等を必要とせずマーカーを計測対象に設置するのみで計測することが可能であるが，マーカーとセンサ（カメラ）の間で光が遮断されると計測できないという欠点がある．そのため，体内にある術具先端の位置・姿勢を直接計測することはできず，体外の術具根元の位置姿勢を計測し，順運動学を解くなどして術具先端位置を求める必要がある．従来の直線状鉗子型のロボット鉗子の位置・姿勢計測は，これが剛体であることから体外に置いた鉗子基部の位置を光学式位置計測装置で計測し，ロボットの関節角などの内部データから鉗子手先の位置・姿勢を計算することが可能であったが，軟性内視鏡型の能動鉗子の場合は動作によってその形状が時々刻々変化することから，鉗子先端の位置・姿勢を直接計測する必要がある．そのような用途に適したセンサとして，磁気式位置姿勢計測装置がある[5]．しかしながら磁気式センサはMRIの強力な磁場のもとでは使用不可能である．

MRI本体を利用した位置計測手法としては，傾斜磁場を利用する方法や小型受信コイル自体の位置を計測するアクティブトラッキングが報告されている．両者とも体内の特定点の位置を計測することができる．傾斜磁場による方式は，小型コイルで傾斜磁場の変化によって生じる誘導電流を計測することで，MRI下における位置と姿勢を計測するものである[6]．磁場を用いるため光学式にみられる光路遮断により計測が不可能になるといった事態はない．しかし，傾斜磁場の変化が小さい磁場中心付近では姿勢計測精度が悪いという報告がある[7]．磁場中心は画像が最も高コントラストで得られる場所であるため，その付近で計測精度が悪いことは大きな問題である．他の手法として，小型受信コイルを用いるアクティブトラッキングがある[8]．これは，小型受信コイルで位相エンコードを行わずに周波数エンコードのみで計測を行い，小型受信コイルの三次元位置を高速に測定する手法である．体内に小型受信コイルを挿入した状態で得られるプロジェクションデータはコイル近傍にのみ信号が得られる．すなわちピーク位置がコイルの一次元位置を示しており，XYZ各軸方向についてプロジェクションデータを得ることで，受信コイルの三次元位置を得ることができる．また，アクティブトラッキングは位相エンコードを行わずに一次元のプロジェクションデータから位置計測を行うため，繰り返し時間の3倍程度の時間で計測を行うことが可能である．この手法はカテーテル先端位置の誘導に応用されている[9-12]．一方，アクティブトラッキングは位置のみの計測であり姿勢を計測することはできないという課題がある．アクティブトラッキングを応用し，多点計測を可能とする方法の報告もなされている[13, 14]．Zhangら[13]は共振回路を二つ用意し，電磁誘導で二つの共振回路を一つの整合回路に接続している．デカップリングダイオードにアクティブに電流を流すことで，どちらの共振回路で計測を行うか選択することができるが，2点を同時に計測することはできない．そのため，2点を計測するためには2倍の時間（繰り返し時間×6）が必要となる．3軸周りの姿勢計測を行う場合は3点以上の計測が必要であるため，共振回路を3つ用意し，それぞれ計測する必要がある．その場合，計測時間が3倍となる（繰り返し時間×9）ことによる時間分解能の低下や回路の大きさが問題となる．例えば繰り返し時間を20 msecとした場合，3点の計測には180 msec必要となる．

Zhangら[14]は，直列分解したインダクタンスを直線状に配置し，2点の三次元位置から針やカテーテルなど直線状の器具に対し，先端の位置と角度を求める手法である．カテーテル先端位置は実際のコイル位置から幾何的に算出しているが，厳密には各コイルのどの位置においてピークが得られているか不明であるため，実際のカテーテル先端の位置姿勢と計測値との間に少なからず誤差を含むと考えられる．また，長軸周りの姿勢を計測できないため，術具先端位置を計測によりキャリブレーションを行うには情報が足りない．さらに，長軸周りの姿勢計測を行っていないことから，その姿勢が重要となる器具（メスや把持鉗子など）には適応できない．

これらの課題を踏まえ，本研究ではアクティブトラッキングを応用した6自由度全ての計測を実現する手法を考案した（拡張アクティブトラッキング，Extended Active Tracking，EAT）．本報告では3点の同時計測が行えることの確認をし，その基礎的評価として1)インダクタンス周辺の水によるノイズを軽減するためのフリップアングル調節，2)拡張アクティブトラッキングによる三次元位置姿勢計測再現性評価，3)拡張アクティブトラッキングによる三