R.E.N.A.L. Nephrometry Score in Clinical Stage T1 Renal Mass: Ramathibodi Hospital Experience

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Objective: *The main treatment strategies for clinical stage T1 renal mass are radical nephrectomy (RN) and partial nephrectomy (PN). Treatment decision depends largely on tumor complexity as assessed by the R.E.N.A.L. nephrometry scoring system. The authors evaluated our experience with R.E.N.A.L. nephrometry score in all patients who underwent surgery.*

Material and Method: *The authors evaluated 61 patients who presented with clinical stage T1 renal mass and underwent radical or partial nephrectomy between 2007 and 2013 at Ramathibodi Hospital. Tumor complexity was quantified by R.E.N.A.L. nephrometry score in all patients using preoperative imaging. Statistical analysis was done to study associations.*

Results: *Sixty-one patients were included in this study, which 34 (55.70%) were male and 27 (44.30%) were female. The most common pathologic report was clear cell renal cell carcinoma followed by angiomyolipoma and papillary renal cell carcinoma. Forty-one patients underwent radical nephrectomy, of whom three, 25, and 10 patients had low, moderate, and high tumor complexity, respectively. Twenty patients underwent partial nephrectomy, of whom 10 patients had low tumor complexity and 10 patients had moderate tumor complexity. No patient had high tumor complexity. In the present study, the function coefficient showed that radius had the most influence on surgical decision-making, followed by nearness to collecting system, exophytic/endophytic, and location. We also developed the Ramathibodi equation to help selecting the proper operation.*

Conclusion: *The R.E.N.A.L. nephrometry score is a feasible and standardized classification system for evaluating renal masses. It could be used to stratify tumor complexity and may help for surgical decision-making.*

Keywords: *Partial nephrectomy, Radical nephrectomy, Renal neoplasm, Nephrometry score*

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Localized renal masses at clinical stages T1 and T2 have increased in incidence owing to more widespread use of cross-sectional imaging. Now, they represent a relatively common clinical scenario. Previously, all were presumed to be malignant and managed aggressively, most often with radical nephrectomy. Now, we recognize great heterogeneity in the tumor biology of these lesions and multiple management strategies are now available, including radical nephrectomy (RN), partial nephrectomy (PN), thermal ablation (TA), and active surveillance (AS)[1]. Nephron sparing surgery has emerged as an oncological equivalent alternative to radical nephrectomy in most cases of localized renal cell carcinoma (RCC)[2].

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Treatment decision depends largely on tumor complexity. The R.E.N.A.L. nephrometry score is a validated tool that characterizes renal tumors based on several objective anatomical criteria[3]. This scoring system accounts for tumor size, tumor depth, proximity to the collecting system, tumor positioning in the anterior/posterior plane, and tumor location with respect to polarity. Studies of the R.E.N.A.L. nephrometry system has shown that tumor scores correlate with surgical outcomes and complications[4].

R.E.N.A.L. nephrometry scores have not been applied in Thailand. Therefore, the authors evaluated the validity with R.E.N.A.L. nephrometry scores for clinical stage T1 renal mass.

Material and Method

Patient population

Before investigation, the present study was ethically approved by the Institutional Review Board of Ramathibodi Hospital. The authors began by

retrospectively reviewing the medical records of the 61 patients who presented with clinical stage T1 renal mass and underwent radical or partial nephrectomy and met study inclusion criteria between 2007 and 2013. Study inclusion criteria included age greater than 18 years, availability of CT scan on PACs, availability of operative detailed, and pathological report. Patients who had abnormal kidney (ADPKD, parenchymatous disease, or atrophic kidney) were excluded from analysis. R.E.N.A.L. nephrometry scores were measured in all patients using preoperative imaging. This score can be used as a decision point in treatment algorithms.

Renal tumor characterization

Preoperative computerized tomography imaging was reviewed in the axial and coronal planes. Tumors were classified by the R.E.N.A.L. nephrometry score, as described by Kutikov and Uzzo[3]. Each feature in the nephrometry score is designated by an English letter, forming the acronym R.E.N.A.L.: (R)adius (scores tumor size as maximal diameter), (E)xophytic/endophytic properties of the tumor, (N)earness of the deepest portion of the tumor to the collecting system or sinus, (A)nterior (a)/posterior (p) descriptor, and the (L)ocation relative to the polar line. Of the five components, four (R.E.N.L.) are scored on a 1, 2, or 3-point scale. The fifth descriptor (A) is a suffix that describes the mass as primarily located anterior (a) or posterior (p) to the coronal plane of the kidney. The suffix x is assigned to the tumor if an anterior or posterior designation is not possible. An additional suffix h is used to designate a hilar. Renal tumors with a R.E.N.A.L. nephrometry score of 4 to 6, 7 to 10, and greater than 10 were classified as low, intermediate, and high complexity, respectively. Details of the scoring system are summarized in Table 1[3].

Statistical analysis

Patient demographic and clinical characteristics were summarized using descriptive statistics. Discriminant analysis was performed to Standardized Canonical Discriminant Function Coefficients and Fisher's linear discriminant functions. Statistical analyses were performed with SPSS version 11.

Results

Sixty-one patients were included in the present study, of whom 34 (55.74%) were male and 27 (44.26%) were female. Mean age was 62.46±12.21 years. Patient characteristics were summarized in Table 2.

From the present study of clinical T1 renal mass, the most common pathologic report was clear cell renal cell carcinoma (RCC) 44 (72.13%), followed by angiomyolipoma and papillary RCC, found in five (8.20%). Chromophobe RCC was found in two (3.28%) patients (Table 2).

Forty-one patients underwent radical nephrectomy, of whom 24 (39.34%) patients underwent laparoscopic radical nephrectomy (LRN) and 17 (27.87%) patients underwent open radical nephrectomy (ORN). The patients who underwent LRN, three patients had low tumor complexity, 15 patients had moderate tumor complexity, and six patients had high tumor complexity. For the patients who underwent ORN, 10 patients had

Table 1. R.E.N.A.L. nephrometry score

	1 point	2 points	3 points
Radius (maximal diameter in cm)	≤4	>4 but <7	≥7
Exophytic/endophytic properties	≥50%	<50%	Entirely endophytic
Nearness of the tumor to the collecting system or sinus (mm)	≥7	>4 but <7	≤4
Anterior/posterior	No points given	Mass assigned a	Descriptor of a, p or x
Location relative to the polar line*	Entirely above the upper or below the lower polar line	Lesion crosses polar line	>50% of mass is across polar line or mass crosses the axial renal midline or mass is entirely between the polar lines

* Suffix "h" assigned if the tumor touches the main renal artery of vein

a: assigned if the tumor locates at anterior, p: assigned if the tumor locates at posterior, x: assigned if an anterior or posterior designation is not possible, h: assigned if the tumor touches the main renal artery of vein

moderate tumor complexity and seven patients had high tumor complexity. In contrast, 20 patients underwent partial nephrectomy, 12 (19.67%) patients underwent laparoscopic partial nephrectomy (LPN), seven (11.48%) patients underwent open partial nephrectomy (OPN), and one (1.64%) patient underwent robotic-assisted laparoscopic partial nephrectomy (RALPN). For the patients who underwent LPN, six patients had low tumor complexity and six patients had moderate tumor complexity. For the patients who underwent OPN, three patients had low tumor complexity and four patients had moderate tumor complexity. One RALPN patient had low tumor complexity (Table 3).

In 2009, the American Joint Committee on Cancer (AJCC) proposed a revision of the TNM system that is now the recommended staging system for RCC. The clinical stage T1 renal mass was subdivided: T1a represents tumor size of 4 cm or less, and T1b represents tumor size between 4 and 7 cm[5]. In clinical stage T1a patients, seven patients underwent radical nephrectomy, of whom one patient had low tumor complexity and six patients had moderate tumor complexity.

Seventeen patients underwent partial nephrectomy, of whom 10 had low tumor complexity, and seven had moderate tumor complexity (Table 4). For patients with clinical stage T1b, 34 patients underwent radical nephrectomy, of whom two patients had low tumor complexity, 19 patients had moderate tumor complexity, and 13 patient had high tumor complexity. Three patients underwent partial nephrectomy as they had moderate tumor complexity (Table 4).

The discriminant analyses of function coefficients were performed in independent variables (R, E, N, L) and found that radius had the most influence on the surgical decision-making followed by nearness to collecting system, exophytic, and location. The function coefficients of independent variable were 0.847, 0.393, 0.365, and 0.008, respectively (Table 5).

The discriminant analysis of Fisher's linear discriminant functions was performed (Table 5). The authors have developed the Ramathibodi's equation to

Table 2. Patient characteristics and pathological diagnosis of renal mass

	Total (n = 61)
Patient characteristics	
Gender	
Male	34 (55.7%)
Female	27 (44.3%)
Mean age ± SD (year)	62.46±12.21 (30-87)
Pathological diagnosis	
Clear cell RCC	44 (72.1%)
Papillary RCC	5 (8.2%)
AML	5 (8.2%)
Chromophobe RCC	2 (3.3%)
Hemorrhage and necrotic tissue	1 (1.6%)
Metastatic carcinoma of cervix	1 (1.6%)
Metastatic papillary carcinoma of thyroid	1 (1.6%)
Oncocytoma	1 (1.6%)
Benign mesenchymal tumor	1 (1.6%)

RCC = renal cell carcinoma; AML = acute myeloid leukemia

Table 3. Score assignments for 61 consecutive masses resected at Ramathibodi Hospital

	No. radical nephrectomy (n = 41)		No. partial nephrectomy (n = 20)			Total (n = 61)
	LRN	ORN	RALPN	LPN	OPN	
No. points	24 (39.3%)	17 (27.9%)	1 (1.6%)	12 (19.7%)	7 (11.5%)	61 (100%)
Complexity						
Low	3 (4.9%)	0	1 (1.6%)	6 (9.8%)	3 (3.9%)	13 (21.3%)
Moderate	15 (24.6%)	10 (16.4%)	0	6 (9.8%)	4 (6.6%)	35 (57.4%)
High	6 (9.8%)	7 (11.5%)	0	0	0	13 (21.3%)
Suffix						
a	8 (13.1%)	6 (9.8%)	0	9 (14.8%)	5 (8.2%)	28 (45.9%)
p	6 (9.8%)	3 (4.9%)	0	2 (3.3%)	1 (1.6%)	12 (19.7%)
x	8 (13.1%)	6 (9.8%)	0	1 (1.6%)	1 (1.6%)	16 (26.2%)
h	2 (3.3%)	2 (3.3%)	1 (1.6%)	0	0	5 (8.2%)

LRN = laparoscopic radical nephrectomy; ORN = open radical nephrectomy; RALPN = robotic-assisted laparoscopic partial nephrectomy; LPN = laparoscopic partial nephrectomy; OPN = open partial nephrectomy
a: assigned if the tumor locates at anterior, p: assigned if the tumor locates at posterior, x: assigned if an anterior or posterior designation is not possible, h: assigned if the tumor touches the main renal artery of vein

Table 4. Score assignments in clinical stage T1a and T1b renal mass

Clinical stage T1a renal mass	No. radical nephrectomy (n = 7)		No. partial nephrectomy (n = 17)			Total (n = 24)
	LRN	ORN	RALPN	LPN	OPN	
No. points	3 (12.5%)	4 (16.6%)	1 (4.2%)	10 (41.7%)	6 (25.0%)	24 (100%)
Complexity						
Low	1 (4.2%)	0	1 (4.2%)	6 (25.0%)	3 (12.5%)	11 (45.8%)
Moderate	2 (8.3%)**	4 (16.6%)*	0	4 (16.6%)	3 (12.5%)	13 (54.2%)
High	0	0	0	0	0	0
Suffix						
a	1 (4.2%)	3 (12.5%)	0	8 (33.3%)	5 (20.8%)	17 (70.8%)
p	1 (4.2%)	1 (4.2%)	0	1 (4.2%)	0	3 (12.5%)
x	1 (4.2%)	0	0	1 (4.2%)	1 (4.2%)	3 (12.5%)
h	0	0	1 (4.2%)	0	0	1 (4.2%)
Clinical stage T1b renal mass	No. radical nephrectomy (n = 34)		No. partial nephrectomy (n = 3)			Total (n = 37)
	LRN	ORN	RALPN	LPN	OPN	
No. points	21 (56.8%)	13 (35.1%)	0	2 (5.4%)	1 (2.7%)	37 (100%)
Complexity						
Low	2 (5.4%)	0	0	0	0	2 (5.4%)
Moderate	13 (35.1%)****	6 (16.2%)	0	2 (5.4%)	1 (2.7%)***	22 (59.5%)
High	6 (16.2%)	7 (18.9%)*	0	0	0	13 (35.1%)
Suffix						
a	7 (18.9%)	3 (8.1%)	0	1 (2.7%)	0	11 (29.7%)
p	5 (13.5)	2 (5.4%)	0	1 (2.7%)	1 (2.7%)	9 (24.3%)
x	7 (18.9%)	6 (16.2%)	0	0	0	13 (35.1%)
h	2 (5.4%)	2 (5.4%)	0	0	0	4 (10.8%)

* Convert from LRN to ORN due to bleeding at hilum
** Convert from LPN to LRN due to margin status
*** Convert from LPN to OPN due to bleeding
**** Convert from LPN to LRN due to renal vein injury
a: assigned if the tumor locates at anterior, p: assigned if the tumor locates at posterior, x: assigned if an anterior or posterior designation is not possible, h: assigned if the tumor touches the main renal artery of vein

Table 5. Show standardized canonical discriminant function coefficients and Fisher's linear discriminant functions

Standardized canonical discriminant function coefficients		
Number	Independent variables	Function coefficients
1	R	0.847
2	E	0.365
3	N	0.393
4	L	0.008

Fisher's linear discriminant functions			
Number	Independent variables	Radical nephrectomy	Partial nephrectomy
1	R	12.585	7.667
2	E	5.001	3.871
3	N	5.730	4.281
4	L	1.740	1.720
	(Constant)	-26.573	-13.887

calculate and choose the preferred type of operation. For radical nephrectomy;

$Y_1 = -26.573+12.585(R)+5.001(E)+5.730(N)+1.740\ (L)$

For Partial nephrectomy;

$Y_2 = -13.887+7.667(R)+3.871(E)+4.281(N)+1.720(L)$

The independent variable (R, E, N, L) can be substituted in two equations to calculate the dependent variable (Y_1 for radical nephrectomy and Y_2 for partial nephrectomy). For the new case, the operation was preferred in the more value of dependent variable (Y). For example, a 5 cm, more than 50% exophytic tumor, 3 mm from the sinus, anteriorly crossing the polar line is designated 2+1+3+a+2 = 8a, moderate complexity. The independent variables (R, E, N, L) can be substituted in two equations, $Y_1 = -26.573+12.585(2)+5.001(1)+5.730(3)+1.740(2) = 24.268$ and $Y^2 = -13.887+7.667(2)+3.871(1)+4.281(3)+1.720(2) = 21.601$. In this case, the type of operation was radical nephrectomy.

Discussion

In management strategies for localized renal masses, clinical stages T1 and T2, are now available, including radical nephrectomy (RN), partial nephrectomy (PN), thermal ablation (TA), and active surveillance (AS)[1]. Nephron sparing surgery has emerged as an oncologically equivalent alternative to radical nephrectomy in most cases of localized RCC[2]. Standardized reporting of renal tumor size, location and depth are essential for consistent decision-making and effective comparisons, particularly as data emerge suggesting a relationship between renal mass anatomy, pathology, and prognosis[6,7].

R.E.N.A.L. nephrometry score was assigned to all identified lesions, as described by Kutikov and Uzzo[3]. Components include maximal tumor diameter, tumor exophytic/endophytic properties, nearness of the tumor to the collecting system or renal sinus, the anterior/posterior description of the tumor and tumor location relative to polar lines as described above.

Studies of the R.E.N.A.L. nephrometry system show that tumor scores correlate with surgical outcomes and complications. Initially used as a decision point in treatment algorithms. Canter et al[4] demonstrated that patients treated with radical nephrectomy (RN) have significantly higher size (R), central proximity (N), and location (L) component scores, more often hilar compared with patients who underwent partial nephrectomy (PN), and concluded that total Nephrometry Score and its individual components correlate with surgical decision-making. Similarly, Rosevear et al[8], who evaluated the utility of the R.E.N.A.L. scoring system in predicting operative approach and risk of complications, found that patients underwent either RN (158) or PN (91) with average R.E.N.A.L. scores of 8.9 and 6.3, respectively. R.E.N.A.L. scores were higher in patients with PN who developed complications than in patients with PN who did not develop complications (6.9 vs. 6.0, $p = 0.02$), with no difference noted among patients with RN developing complications. They concluded that the R.E.N.A.L. system accurately predicted surgeon operative preference and risk of complications for patients undergoing PN.

The R.E.N.A.L. nephrometry score was used to predict adverse perioperative outcomes. Hayn et al[9], who assessed the use of the R.E.N.A.L. nephrometry score to predict surgical outcomes for patients undergoing laparoscopic partial nephrectomy, found that there was a significant difference in warm ischemia time (16 vs. 23 vs. 31 min; $p<0.001$), estimated blood loss (163 vs. 312 vs. 317 mL; $p = 0.034$) and length of hospital stay (1.2 vs. 1.9 vs. 2.3 days; $p<0.001$) between the low, intermediate and high score groups, respectively. They commented that patients undergoing LPN with a higher R.E.N.A.L. Nephrometry score was significantly associated with an increased estimated blood loss, warm ischemia time, and length of hospital stay.

In the postoperative outcomes, Bruner et al[10] demonstrated that tumors that were <50% exophytic (OR 16.65; 95% CI 2.75-100.71; $p = 0.002$), completely endophytic (OR 17.02; 95% CI 2.88-100.55; $p = 0.002$), or located at the renal pole (OR 4.34; 95% CI 1.30-14.53; $p = 0.017$) were associated with urine leak. They concluded that the R.E.N.A.L. nephrometry score is associated with risk of urine leak after partial nephrectomy. Similar findings were noted in recent studies. Simhan et al[11] evaluated whether increasing renal tumor complexity, quantitated by nephrometry score, was associated with increased complication rates following PN using the Clavien-Dindo classification system. They concluded that increasing tumor complexity is associated with the development of major complications after PN.

Other study showed association between anatomical tumor complexity and histological features after nephrectomy. Kutikov et al[12] initially observed that increasing nephrometry scores are correlated with tumor grade and histology.

The authors assessed R.E.N.A.L. nephrometry score in clinical stage T1 renal mass in patients who underwent radical nephrectomy and partial nephrectomy at Ramathibodi Hospital. The authors developed Ramathibodi's equation to calculate the probability type of the operation. In additional to the R.E.N.A.L. nephrometry score, the equation provides a useful, flexible, and reproducible tool to objectify salient renal anatomy and may help with surgical decision-making.

The presented five patients had surgery that changed during operation. Three cases were switched from laparoscopy to open surgery. In the first case, the patient with clinical stage T1a renal mass (moderate tumor complexity) underwent LRN but converted to ORN due to bleeding at hilum. In the second case, the patient with clinical stage T1b renal mass (high tumor complexity) underwent LRN but had to be converted to ORN due to bleeding at hilum. For the last case, the patient with clinical stage T1b renal mass (moderate tumor complexity) underwent LPN but was converted to OPN due to bleeding from renal parenchyma. There were two cases to switch from partial nephrectomy to

radical nephrectomy. In the first case, the patient with clinical stage T1a renal mass (moderate tumor complexity) underwent LPN but was converted to LRN because of margin status. For the second case, the patient with clinical stage renal mass (moderate tumor complexity) underwent LPN but was convert to LRN due to injury to the renal vein.

The present study has several limitations. The presented is a retrospective analysis, the population could have been larger, and the population was only at Ramathibodi Hospital.

Conclusion

The R.E.N.A.L. nephrometry score was a standardized classification system of renal masses. It can be used to stratify tumor complexity (low, moderate, high), used as a decision point in treatment algorithms and a predictor of adverse perioperative outcomes and postoperative complications.

What is already known on this topic?

R.E.N.A.L. nephrometry score was described by Kutikov and Uzzo. The score is a validated tool that characterizes renal tumors based on several objective anatomical criteria. Foreign studies of the R.E.N.A.L. nephrometry system show that tumor scores correlate with surgical outcomes and complications. Some studies were used to predict adverse perioperative outcomes, postoperative outcomes. Other study showed association between anatomical tumor complexity and histological features after nephrectomy. The R.E.N.A.L. nephrometry scores have not been applied in Thailand. Therefore, the authors evaluated the validity with R.E.N.A.L. nephrometry scores for clinical stage T1 renal mass.

What this study adds?

The authors evaluated the validity with the R.E.N.A.L. nephrometry scores for clinical stage T1 renal mass, and developed Ramathibodi's equation to calculate and choose the preferred type of the operation. It could be used to stratify tumor complexity and may help for surgical decision-making.

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Potential conflicts of interest

None.

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การประเมินค่า R.E.N.A.L. nephrometry score ในก้อนเนื้องอกขนาดเล็กในไต: ประสบการณ์โรงพยาบาลรามาธิบดี

ศิริอนันต์ ประสิทธิ์, ปกเกศ ศิริศรีตรีรักษ์, เปรมสันต์ สังฆ์คุ้ม, กิตติณัฐ กิจวิกัย, วิทย์ วิเศษสินธุ์, วิสูตร คงเจริญสมบัติ, เจริญ ลีนานุพันธุ์, วชิร คชการ

วัตถุประสงค์: *การรักษาเนื้องอกขนาดเล็กในไตมีหลายแบบ ตั้งแต่การผ่าตัดไตออกทั้งหมด การผ่าตัดไตออกบางส่วน ซึ่งการที่จะตัดสินใจทำการผ่าตัดอย่างใดอย่างหนึ่งนั้น จะต้องประเมินจากค่า R.E.N.A.L. nephrometry score การศึกษานี้เพื่อหาค่า R.E.N.A.L. nephrometry score ในผู้ป่วยที่เข้ารับการผ่าตัดในโรงพยาบาลรามาธิบดี*

วัสดุและวิธีการ: *ศึกษาผู้ป่วยที่มีก้อนเนื้องอกขนาดเล็กในไตจำนวน 61 ราย ที่เข้ารับการผ่าตัดไตออกทั้งหมดหรือผ่าตัดไตออกบางส่วน ตั้งแต่ พ.ศ. 2550 ถึง พ.ศ. 2556 โดยคำนวณค่า R.E.N.A.L. nephrometry score จากผลการตรวจทางรังสีก่อนผ่าตัด*

ผลการศึกษา: *ผู้ป่วยจำนวน 61 ราย พบว่า 34 ราย (55.70%) เป็นเพศชาย และ 27 ราย (44.30%) เป็นเพศหญิง ลักษณะทางพยาธิวิทยาที่พบมากที่สุดคือ clear cell renal cell carcinoma ตามด้วย angiomyolipoma และ papillary renal cell carcinoma ผู้ป่วย 41 ราย เข้ารับการผ่าตัด radical nephrectomy พบว่า 3 ราย อยู่ในกลุ่ม low tumor complexity, 25 ราย อยู่ในกลุ่ม moderate tumor complexity และ 10 ราย อยู่ในกลุ่ม high tumor complexity ผู้ป่วย 20 ราย เข้ารับการผ่าตัด partial nephrectomy พบว่า 10 ราย อยู่ในกลุ่ม low tumor complexity, 10 ราย อยู่ในกลุ่ม moderate tumor complexity ไม่มีผู้ป่วยในกลุ่ม high tumor complexity การศึกษาของสัมประสิทธิ์ฟังก์ชันนี้แสดงให้เห็นว่ารัศมี (radius) มีอิทธิพลของการตัดสินใจการผ่าตัดมากที่สุด ตามมาด้วย ความใกล้ต่อกรวยไต (nearness to collecting system) ลักษณะของก้อนที่ยื่นมานอกไต (exophytic/endophytic) และตำแหน่งของก้อน (location) นอกจากนี้ยังพัฒนาสมการรามาธิบดีที่จะช่วยให้การเลือกการดำเนินการที่เหมาะสม*

สรุป: *ค่า R.E.N.A.L. nephrometry score เป็นระบบการจัดหมวดหมู่และเป็นมาตรฐานสำหรับการผ่าตัดเนื้องอกในไต โดยการแบ่งลักษณะก้อนเนื้องอกตามความซับซ้อนของเนื้องอกและอาจช่วยในการตัดสินใจในการผ่าตัด*
