FRONTAL RECESS ANATOMY AND ITS ASSOCIATION WITH THE DEVELOPMENT OF FRONTAL SINUSITIS: COMPUTED TOMOGRAPHY STUDY

DR HAFIZAH HUSNA JOHARI

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT FOR THE REQUIREMENT OF THE DEGREE OF MASTER OF MEDICINE

(OTORHINOLARYNGOLOGY – HEAD AND NECK SURGERY)

SCHOOL OF MEDICAL SCIENCES
UNIVERSITI SAINS MALAYSIA
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ABSTRAK (Bahasa Melayu)

Objektif: Kajian ini dijalankan untuk meneliti variasi anatomi sel-sel frontal recess dan perkaitannya dengan resdung frontal. Kejadian frontal recess di dalam populasi, kewujudan variasi sel-sel frontal recess dalam resdung kronik dan bukan resdung kronik, serta kaitan variasi sel-sel frontal recess dengan pembentukan resding frontal juga dikaji.

Kaedah: Ini merupakan kajian pemerhatian, keratan rentas tomografi komputer sinus hidung yang telah dijalankan ke atas pesakit-pesakit di Hospital Universiti Sains Malaysia dan Hospital Sultanah Bahiyah dari Januari 2009 sehingga Disember 2016.

Keputusan: Sebanyak 312 bahagian dari 156 imej tomografi komputer pesakit telah dianalisis. Bahagian kiri dan kanan pesakit dikira berasingan. Sejumlah 63 bahagian mengalami resdung frontal, 37 daripadanya adalah pesakit lelaki dan 26 daripadanya adalah perempuan, manakala 249 bahagian selebihnya tiada masalah resdung frontal. Tiada banyak perbezaan dari segi purata umur untuk pesakit resdung frontal (46.51±14.00) dan pesakit tanpa resdung frontal (48.73±16.44). Peratusan bahagian kiri dan kanan serta jantina adalah hampir sama bagi pesakit resdung kronik dan bukan resdung kronik. Dalam kajian kami, sel-sel frontal recess seperti sel agger nasi dijumpai dalam hampir kesemua pesakit 98.1%, sel frontal ethmoidal jenis 1, jenis 2, jenis 3 dan jenis 4 merangkumi 28.8%, 31.1%, 14.4% dan 0%. Manakala sel suprabullar didapati sebanyak 40.3%, sel supraorbital ethmoidal 16.7%, sel frontal bullar 33.0% dan sel inter-frontal sinus septal 10.8%. Kewujudan variasi sel-sel frontal recess juga dibandingkan dengan populasi-

populasi lain. Terdapat perkaitan statistic yang ketara di antara kewujudan sel frontal bullar dan pembentukan resdung frontal (nilai $p < 0.001$)

Kesimpulan: Variasi sel-sel frontal recess pada pesakit-pesakit di Malaysia hampir sama dengan populai-populasi Asia yang lain seperti Jepun, Taiwan, Chinese dan Korea. Kajian kami menunjukkan sel frontal bullar mempunyai perkaitan yang ketara dengan pembentukan resdung frontal berbanding sel-sel frontal recess yang lain. Pemahaman tentang struktur anatomi frontal recess sangat penting kerana ia boleh menjadikan rawatan penyakit resdung kronik Berjaya dan pada masa yang sama ia membantu pakar bedah dalam merancang pembedahan endoskopik sinus untuk mencegah penyakit ini berulang kembali dan mengelakkan dari komplikasi pembedahan.

ABSTRACT (English)

Objective: This study was done to determine frontal recess anatomy cell variations and its association with frontal sinusitis. The incidence of frontal recess cells in the population, the presence of frontal recess cell variations in chronic rhinosinusitis and non-chronic rhinosinusitis and the association of frontal recess cell variation in the development of frontal sinusitis were also assessed.

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in 40.3%, supraorbital ethmoid cells 16.7%, frontal bullar cell 33.0% and inter-frontal sinus septal cells 10.8%. The presence of frontal recess cells variation was compared with other populations. There was a statistically significant association between the presence of frontal bullar cell and the development of frontal sinusitis (p value < 0.001).

Conclusion: The frontal recess cells variation in Malaysian subjects were almost similar to those reported in other Asian populations such as Japanese, Taiwanese, Chinese and Korean. Our study found that frontal bullar cells had a significant association with the development of frontal sinusitis than other frontal recess cells. The understanding of the frontal recess anatomical structures was very important as this would lead to a successful treatment of CRS and at the same time it helped the surgeon to have a better plan of endoscopic sinus surgery to prevent the disease recurrence and surgical complication.

Chapter 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

Chronic rhinosinusitis with or without nasal polyps is an inflammatory disorder of the nose and the paranasal sinuses. It is characterized by two or more symptoms of nasal congestion or anterior/posterior nasal discharge with either facial pain or reduced/absent sense of smell, lasting more than 12 weeks. In addition, with either endoscopic signs of polyps, mucopurulent discharge and/or edema primarily in middle meatus or computed tomography (CT) changes with mucosal changes within the osteomeatal complex and/or sinuses.[1]

The paranasal sinuses (PNS) can be divided into anterior and posterior groups. The anterior group of PNS consists of maxillary, frontal and anterior ethmoidal sinuses. The posterior group of PNS includes sphenoid and posterior ethmoidal sinuses.[2] It is very important to have adequate ventilation and drainage for healthy normal functioning sinuses. Normal draining sinuses needs a patent sinus ostium connecting the sinuses to the nasal cavity.

The mucociliary system plays a vital role in draining the mucus produced within the sinuses into the nasal cavity. In the frontal sinus, the mucus is transported to its ostium located inferiorly.[2] Usually acute frontal sinusitis heals fast and chronic frontal sinusitis is less frequent as compared to maxillary sinusitis because of the high position of the maxillary sinus ostium, resulting in less favorable drainage. The width and course of the frontonasal recess, be it straight or curved, depends on the size and number of the anterior ethmoidal cells, some of which develop into the frontal sinus and are then called 'frontal cells' or 'frontal bulla'. [2]

Kuhn proposed that there is various type of cells that surround the frontal recess (Figure 1). There are agger nasi cells (ANC), supraorbital ethmoidal cells (SOEC), frontoethmoidal cells type 1, type 2, type 3 and type 4 (FC1, FC2, FC3, FC4), frontal bulla cells (FBC), supra bulla cells (SBC) and interfrontal sinus septal cell (IFSSC).[3]

Frontal sinus is regarded as one of the sinuses that are difficult to approach as it is located higher than the other paranasal sinus and is surrounded by complex cell structures with a very narrow drainage pathway. It is vital for surgeons to have a high-quality CT scan of PNS to assess the anatomy and drainage pathway of the frontal sinus prior to surgery.[4] CT scan also shows the surgeon the extent of the pathology, the aggressiveness of the disease state, and involvement of the adjacent vital structures, thus reducing the risk of potential complications during surgery.[5]

There have been multiple studies using cadaveric as well as studies on CT evaluation of the frontal recess anatomy cell variations.[4] Most of the literature published on the anatomical variants of the frontal recess anatomy have been conducted on Caucasian, Middle-eastern and Chinese populations. In view of the critical importance of the various landmarks as well as the scarcity of information on Malaysian population, this study was conducted to explore the frontal recess cell variations in Malaysian patients. To date, there is no available literature on Malaysian population regarding the various cells which encroach on the frontal recess and its association in the genesis of CRS with or without nasal polyps.

Chapter 2

OBJECTIVES OF THE STUDY

CHAPTER 2: OBJECTIVES

2.1 GENERAL OBJECTIVE

To determine frontal recess anatomy cell variations and its association with frontal sinusitis.

2.2 SPECIFIC OBJECTIVES

i. To determine the incidence of frontal recess cells in the population.

ii. To identify the presence of frontal recess cell variations in chronic rhinosinusitis (CRS) and non-chronic rhinosinusitis (non-CRS).

iii. To determine the association of frontal recess cell variation in the development of frontal sinusitis.

Chapter 3

MANUSCRIPT

3.1 TITLE PAGE

Original Article

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3.2 ABSTRAK (Bahasa Melayu)

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Keywords: Frontal, frontal sinusitis, frontal sinus, rhinosinusitis, computed tomography

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3.4 METHODOLOGY

This is an observational, retrospective cross-sectional study of contrast-enhanced computed tomography of PNS (CECT PNS) that had been performed on patients in Hospital Universiti Sains Malaysia (HUSM) and Hospital Sultanah Bahiyah (HSB). This study was conducted from January 2009 until December 2016.

The study population was Malaysians 18 years and older. The source population is patients who attended Otorhinolaryngology (ORL) clinic in both hospitals. The patients had clinical and endoscopic findings suggestive of CRS and underwent CECT PNS at radiology department. Patients from the emergency department who underwent CT brain until cervical, including paranasal sinus or reconstructed paranasal sinus for other indications without past medical history of CRS were also recruited as our control group.

Both hospitals used Siemens SOMATOM CT scanner with 1.25mm-thick-axial, coronal and sagittal cuts. CT scan in HUSM used Siemens SOMATOM definition AS+ 128 slice, 64 detectors (2009). In HSB, CT scan images were obtained via Siemens SOMATOM emotion-6 6 slice. There is difference in number of slices per one rotation, but the quality of the images is still the same which is 1.25mm cut in all three planes. The reconstructed multiplanar slices can also be reconstructed to 1.25mm thickness in axial-coronal-sagittal cut. The CT scans were done following their respective protocols in the hospitals.

Data was retrieved from medical record unit and manually from the CT scan registry book available in the record and filing office of the diagnostic imaging department or from the PACS online. The online PACS-IW system was accessed to trace the type of CT scan that every patient had undergone. The CT scans of paranasal sinuses were retrieved and saved into a DVD-R. These images were subsequently transferred into the OSIRIX 64-bit DICOM Viewer imaging software on a MacBook Pro laptop.

Interpretation and review of the CT PNS in axial, coronal and sagittal planes will be done by one radiologist and one ORL specialist together. Each of them will see all the cases from both hospitals, with any disagreements resolved by consensus. All data obtained were entered in the study proforma. All data obtained were transferred into the Statistical Package for Social Sciences (SPSS) software version 22.0.

3.5 RESULT

A total of 312 sides from 156 patients' CT scan images were analyzed. Left and right sinuses were considered individually. A total of 63 sides showed evidence of frontal sinusitis, 37 were male and 26 were female, whereas 249 sides were clear from frontal sinus disease. It was not much difference in mean age for frontal sinusitis patient (46.51±14.00) and patients without frontal sinusitis (48.73±16.44). The percentage was almost equal for CRS and non-CRS groups regardeless of side and gender (Table 1). The majority of our subjects were Malays which comprised of 139 patients (89.2%), followed by 11 Chinese (7.0%), 4 Indian (2.5%) and only 2 others (1.3%), representing local ethnics' ratio (Table 2).

In our study, the frontal recess cell such as agger nasi cell was found in almost all patients 98.1%, frontal ethmoidal cell type 1, type 2, type 3 and type 4 comprised of 28.8%, 31.1%, 14.4% and 0% respectively. Whereas, suprabullar cell can be seen in 40.3%, supraorbital ethmoid cells 16.7%, frontal bullar cell 33.0% and inter-frontal sinus septal cells 10.8%. The presence of frontal recess cells variation was compared with other populations (Table 3).

A total of patients with frontal sinusitis was 63 in CRS, 68.3% from CRS groups had FBC but 31.7% from non-CRS groups had FBC (Table 4). There was a statistically significant association between the presence of frontal bullar cell and the development of frontal sinusitis (p value < 0.001) (Table 5 and 6)

3.6 DISCUSSION

The frontal recess is a complex space that has a shape of an inverted funnel or cone with the apex at the frontal ostium (Figure 1). Various anterior ethmoid cells, namely frontal recess cells (ANC, FC1-4, SOEC, SBC, FBC, SBC, IFSSC), filled in this space. Due to the intrinsic anatomic complexity of this narrow space, the surgeon must possess a good knowledge of frontal recess anatomy.

In our study, we used the criteria for frontal recess anatomy as proposed by Lee et al, who clarified the definitions of several different types of frontal recess cells.6 We found that the prevalence of ANC is 98% in our populations, almost similar prevalence with Korean and Chinese groups, 94% and 94.1% respectively and most of other studies of Asian and Caucasian populations showed more than 80% prevalence.7,8 ANC was the most anterior ethmoid cell pneumatizing laterally into the lacrimal bone (Figure 2). Due to its high prevalence in the majority of cases, ANC can be used as an anatomical landmark (the agger nasi cell approach) to access the frontal recess area by opening the anteroinferior wall of the ANC followed by removal of the medial, roof and posterior walls of the ANC.9 However, the presence of ANC did not correlate with a greater incidence of frontal sinusitis in our series. DelGaudio et al. reported there was no significant difference in the frequency of frontal sinusitis in patients with or without ANC in primary or revision sinuses.10 Angélico et al. reported there was no statistically significant difference among the mean values of the ANC and frontal ostium measures that were associated with the development of frontal sinusitis.11

Of all the frontoethmoidal cells identified in 232 sides of frontal recesses, the prevalence of FC1, FC2 and FC3 cells were 28.8%, 31.1% and 14.4%, respectively (Figure 3, 4 and 5). FC1 was the most commonly found frontal recess air cell in our study as well as in the overall cases as reported by DelGaudio et al 15.1%, Han et al 24.4% and Cho et al. 22.8%. FC2 in our subjects was almost as high as Caucasians 20.7% and the prevalence of FC3 was twice the number from other East Asian populations. These discrepancies might be due to racial differences between our South-East Asian races and other East Asian populations. However, there were no FC4 cells identified in our subjects similar to other studies in Taiwanese, Chinese and Korean groups, but Japanese group reported 4 (1.3%) of 300 sides of paranasal sinuses had evidence of FC4. FC4 cells appeared as isolated cells in the frontal sinus and were quite rare.

In our series, all frontoethmoidal cells did not correlate with the high incidence of frontal sinusitis. In contrast with the findings from Meyer et al, they found a greater incidence of frontal sinusitis in patients with FC3 and FC4.12 This could be due to smaller numbers of patients in our series with FC3 and none with FC4. On the other hand, DelGaudio et al. reported that the presence of FC1 to FC4 did not correlate with a higher incidence of frontal sinusitis.10

Almost similar findings found in other East Asian populations, SBC in our series was 40.3%, in line with studies conducted by others, such as Japanese, Taiwanese, Chinese and Korean were all 37.0%, 39.1%, 36.6% and 39.5% respectively (Figure 6).6 IFSSC in our study population 10.8% also showed more consistent percentage with that in East Asian population as well as Caucasian

(Figure 7). SOEC was more frequent 16.7% as compared to other East Asian groups, but less frequent than in Caucasian patients 64.6% (Figure 8).13

In our study, the prevalence of FBC appeared to be higher than in other East Asian group (Figure 9). Our data showed 33.0% which is double in the Korean population 14.0%. This could be due to anatomic variations in our sample group of South-East Asian which inherently are from different ethnicity.

By univariate analysis, the prevalence of ANC, FC1-3, SBC, SOEC and IFSSC failed to show any association with the presence of frontal sinusitis, but FBCs ($p < 0.001$) showed a significant association with frontal sinusitis. The pathophysiology of frontal sinusitis is associated with disturbance of its drainage and ventilation of the sinus via the ostium. Generally, frontal recess cells and their inflammation can influence frontal sinus ventilation by narrowing frontal sinus drainage pathways. Kubota et al. reported that FBC is associated with the development of frontal sinusitis with $p = 0.043$.13

Lien et al. found that the frontoethmoidal cells which are located posterior and posterolateral to the frontal recess (SBC, FBC, SOEC) reveal a more significant association with the development of frontal sinusitis than those anterior to the frontal recess (ANC, FC1-3). The presence of SOEC indicate the highest odds of frontal sinusitis, followed by the presence of SBC, FBC and recessus terminalis.14

Our study revealed that FBC will have significant influence on the development of frontal sinusitis synergistically when other etiologic factor exists such as mucosal inflammation. Another study had shown a number of etiologic factors contributing to the development of frontal sinusitis mainly mucosal disease (67%), retained ethmoid cells (53%), lateralized middle turbinates (30%), retained ANCs (13%), scar tissue (12%), retained frontal cells (8%), and neo-osteogenesis (7%).15

However, this study also had few limitations. CT scan, as a major tool in the study even though has good bony resolution but does not possess similar property for soft tissue. Mucosal contact or other soft tissue abnormality is unable to be comment despite its crucial role in the pathogenesis of CRS. Despite evaluating presence or absence of the cells around the frontal recess, the size or volume of the cells should also be evaluated. Other factors that can contribute to the development of CRS such as mucosal diseases as well as anatomical variations such as deviated nasal septum and lateralized middle turbinate that can cause narrowing of osteomeatal complex as the final drainage pathway of frontal sinus should also be considered in the future study.

3.7 CONCLUSIONS

The frontal recess cells variation in Malaysian subjects are almost similar to those reported in other Asian populations such as Japanese, Taiwanese, Chinese and Korean. Our study found that frontal bullar cells had a significant association with the development of frontal sinusitis than other frontal recess cells.

3.8 REFERENCES

1. Fokkens WJ, Lund VJ, Mullol J, Bachert C, Alobid I, Baroody F, et al. EPOS 2012: European position paper on rhinosinusitis and nasal polyps 2012. A summary for otorhinolaryngologists. Rhinology 2012;50:1–12.

2. Stammberger H, Lund VJ. Anatomy of the nose and paranasal sinuses. Gleeson M, Browning GG, Burton MJ, et al.: Scott Brown's Otorhinolaryngology: Head and Neck Surgery ed 7 London, Edward Arnold, 2008. 2:1315–43

3. Wormald PJ. Surgery of the frontal recess and frontal sinus. Rhinology. 2005;43:82-5.

4. Zojaji R, Nekooei S, Naghibi S, Mazloum Farsi Baf M, Jalilian R, Masoomi M. Accuracy of limited four-slice CT-scan in diagnosis of chronic rhinosinusitis. Eur Ann Otorhinolaryngol Head Neck Dis. 2015;132:333-5.

5. Huang BY, Lloyd KM, DelGaudio JM, Jablonowski E, Hudgins PA. Failed Endoscopic Sinus Surgery: Spectrum of CT Findings in the Frontal Recess. Radiographics. 2009;29:177-95.

6. Lee WT, Kuhn FA, Citardi MJ. 3D computed tomographic analysis of frontal recess anatomy in patients without frontal sinusitis. Otolaryngol Head Neck Surg. 2004;131:164-73.

7. Cho JH, Citardi MJ, Lee WT, Sautter NB, Lee HM, Yoon JH et al. Comparison of frontal pneumatization patterns between Koreans and Caucasians. Otolaryngol Head Neck Surg. 2006;135:780-6.

8. Han D, Zhang L, Ge W, Tao J, Xian J, Zhou B. Multiplanar computed tomographic analysis of the frontal recess region in Chinese subjects without frontal sinus disease symptoms. ORL J Otorhinolaryngol Relat Spec. 2008;70:104-12.

9. Wormald PJ: The axillary flap approach to the frontal recess. Laryngoscope 2002;112: 494–9.

10. DelGaudio JM, Hudgins PA, Venkatraman G, Beningfield A. Multiplanar computed tomography analysis of frontal recess cells: effect on frontal isthmus size and frontal sinusitis. Arch Otolaryngol Head Neck Surg. 2005;131:230-5.

11. Angélico Jr FV, Rapoport PB. Analysis of the Agger nasi cell and frontal sinus ostium sizes using computed tomography of the paranasal sinuses. Braz J Otorhinolaryngol. 2013;79:285-92.

12. Meyer TK, Kocak M, Smith MM. Coronal computed tomography analysis of frontal cells. Am J Rhinol 2003;17:163–8.

13. Kubota K, Takeno S, Hirakawa K. Frontal recess anatomy in Japanese subjects and its effect on the development of frontal sinusitis: computed tomography analysis. J Otolaryngol Head Neck Surg. 2015;44:21.

14. Lien CF, Weng HH, Chang YC, Lin YC, Wang WH. Computed tomographic analysis of frontal recess anatomy and its effect on the development of frontal sinusitis. Laryngoscope. 2010;120:2521–7.

15. Otto KJ, DelGaudio JM. Operative findings in the frontal recess at time of revision surgery. Am J Otolaryngol. 2010;31:175-80.

3.9 TABLES AND FIGURES

Table 1. Characteristics of patient's comparison based on groups and FS status (n=312)

Variable	CRS		Total	Non-CRS n(%)
	FS^+ n(%)	FS^- n(%)		
Age (mean±SD)	46.51±14.00	48.73±16.44	47.83±15.49	51.69±19.27
Side				
Left	31(49.2)	47(50.5)	78(50.0)	79(50.6)
Right	32(50.8)	46(49.5)	78(50.0)	77(49.4)
Gender				
Male	37(58.7)	55(59.1)	92(59.0)	92(59.0)
Female	26(41.3)	38(40.9)	64(41.0)	64(41.0)

Table 2. Local races demographic data

Race	Case	%
Malay	139	89.2
Chinese	11	7.0
Indian	4	2.5
Others	2	1.3
Total	156	100.0

Table 3. Comparison of incidence of frontal recess cells in various population

Cell types	Our cases; 312 sides, no. (%)	Japanese; 300 sides, no. (%)	Taiwanese; 363 sides, no. (%)	Chinese; 404 sides, no. (%)	Korean; 114 sides, no. (%)	Caucasian; 82 sides, no. (%)
ANC	306 (98.1)	265 (88.0)	323 (89.0)	380 (94.1)	107 (94.0)	71 (86.6)
FC1	90 (28.8)	111 (37.0)	78 (21.5)	98 (24.4)	26 (22.8)	29 (35.4)
FC2	97 (31.1)	19 (6.3)	38 (10.5)	28 (7.0)	16 (14.0)	17 (20.7)
FC3	45 (14.4)	13 (4.3)	28 (7.7)	33 (8.2)	9 (7.9)	7 (8.5)
FC4	0 (0)	4 (1.3)	0 (0)	0 (0)	0 (0)	0 (0)
SBC	126 (40.3)	111 (37.0)	142 (39.1)	148 (36.6)	45 (39.5)	9 (11.0)
SOEC	52 (16.7)	18 (6.0)	28 (7.7)	22 (5.4)	3 (2.6)	53 (64.6)
FBC	104 (33.0)	21 (7.0)	23 (6.3)	36 (9.0)	16 (14.0)	5 (6.1)
IFSSC	34 (10.8)	26 (8.6)	35 (9.6)	25 (12.4)	10 (8.8)	6 (7.3)

Table 4. Cells variations comparison based on groups (n=312)

Variable	CRS n(%)	Non-CRS n(%)	Total	p-value[a]
FS				
Positive	63 (100.0)	0 (0.0)	63 (100.0)	<0.001
Negative	93 (37.3)	156 (62.7)	249 (100.0)	
FBC				
Positive	71 (68.3)	33 (31.7)	104 (100.0)	<0.001
Negative	85 (40.9)	123 (59.1)	208 (100.0)	
ANC				
Positive	153 (50.0)	153 (50.0)	306 (100.0)	>0.95[b]
Negative	3 (50.0)	3 (50.0)	6 (100.0)	
FC1				
Positive	40 (44.4)	50 (55.6)	90 (100.0)	0.211
Negative	116 (52.3)	106 (47.7)	222 (100.0)	
FC2				
Positive	50 (51.5)	47 (48.5)	97 (100.0)	0.714
Negative	106 (49.3)	109 (50.7)	215 (100.0)	
FC3				
Positive	21 (46.7)	24 (53.3)	45 (100.0)	0.625
Negative	135 (50.6)	132 (49.4)	267 (100.0)	
FC4				
Positive	0 (0.0)	0 (0.0)	0 (0.0)	Not applicable
Negative	156 (50.3)	154 (49.7)	310 (100.0)	
SBC				
Positive	60 (47.6)	66 (52.4)	126 (100.0)	0.489
Negative	96 (51.6)	90 (48.4)	186 (100.0)	
SOEC				
Positive	27 (51.9)	25 (48.1)	52 (100.0)	0.761
Negative	129 (49.6)	131 (50.4)	260 (100.0)	
IFSS right				
Positive	19 (55.9)	15 (44.1)	34 (100.0)	0.467
Negative	137 (49.3)	141 (50.7)	278 (100.0)	