Analysis of Thin-walled Regions in Unruptured Cerebral Aneurysms Using Computational Fluid Dynamics

Emiko Hori MD; Kimiko Umemura Oya; Soshi Okamoto; Michiya Kubo; Satoshi Hori; Takashi Shibata; Yukio Horie; Daina Kashiwazaki; Naoki Akioka; Naoya Kuwayama; Satoshi Kuroda MD PhD

Department of Neurosurgery, Saiseikai Toyama Hospital and University of Toyama, Toyama, Japan

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Emiko HORI[1], Kimiko Umemura OYA[1], Soshi OKAMOTO[1], Michiya KUBO[1], Satoshi HORI[1], Takashi SHIBATA[1], Yukio HORIE[1], Daina KASHIWAZAKI[2], Naoki AKIOKA[2], Naoya KUWAYAMA[2], Satoshi KURODA[2]

[1]Department of Neurosurgery, Saiseikai Toyama Hospital, Toyama, Japan

[2]Department of Neurosurgery, Graduate school of Mediceine and Pharmaceutical Science, University of Toyama, Toyama, Japan

Introduction

- It is not rare that the normal arteries should be dissected from the aneurysmal wall for safe and complete clipping. However, it is sometimes at higher risk for aneurysmal rupture during the dissection especially when the aneurysmal wall is quite thin.
- The purpose of this study was to evaluate the usefulness of preoperative computational fluid dynamics (CFD) to identify the thin-walled cerebral aneurysms before clipping surgery.

Methods; Source of date

- 55 unruptured cerebral aneurysms that were treated by neck clipping were analyzed.
- Men 15 Women 36 (multiple 4 cases)
- Age 44-80 year-old (mean 65.4)
- Location of aneurysm

MCA	38
Acom	4
IC	7
distal ACA	4
A1	2

CFD modeling

- Blood vessel geometry was extracted from MRA, CTA and DSA.
- Segmentation: ziostation (ziosoft, Tokyo, Japan)
- Creation of vascular models, and calculation of hemodynamic factors : hemoscope(EBM, Tokyo, Japan)
- the condition using calculate is below.

HR	75bpm
Density	1050kg/m^3
Viscosity	4.0mPa・s
Flow rate:	$Q=\tau_w \pi/32\mu \times D^3$ ml/min

Analysis of hemodynamic factors

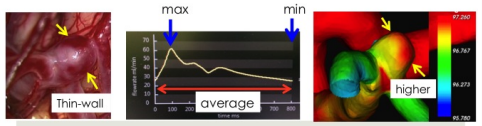
Exam 1) CFD Parameters within Each Aneurysm

Of 55 aneurysms, 54 had 68 points with thin wall than could be defined as a red wall during intraoperative findings.

We calculated the pressure and wall shear stress (WSS) in all 54 aneurysms. Each parameter was expressed as the maximal, minimal, and average values.

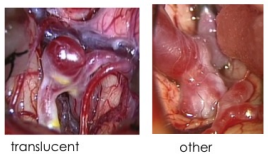
These values were compared between thin-walled points and others within each aneurysm.

In addition, WSS in the thin-walled points was compared with that at the parent artery, and also with the average value of a whole aneurysm.



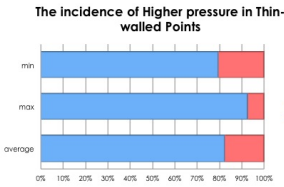
Exam 2) CFD Parameters between Thin-walled Aneurysms and Others

Likewise, CFD parameters, including WSS, flow coefficient, and age, gender, volume, were compared with 18 aneurysms with almost fully translucent wall and 34 aneurysms without.



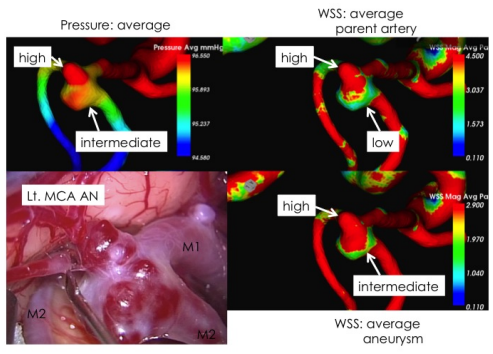
translucent other

Results : Pressure in Thin-walled points



- More than 80% points of thin-wall regions had higher pressure than non-thin-walled points within each aneurysm.

- The WSS at the thin-walled points widely varied among cerebral aneurysms.



Results: Exam 2)

	Translucent	Others	Univariate analysis	Multivariate analysis	OR(95% CI)
Age(years)	64.8±9.9	65.7±6.3	p=0.6993		
Gender					
Men	2	14			
Women	16	20	p=0.0183	p=0.0083	8.37(1.65-68.5)
Volume(mm^3)	56.7±26.6	81.1±73.0	p=0.1792		
Aspect ratio	0.52±0.16	0.64±0.18	p=0.0225	p=0.0829	
Flow coefficient	66.0±31.8	48.5±31.5	p=0.0643	p=0.968	
WSS(Pa)	6.25±4.4	9.1±4.9	p=0.0407	p=0.0419	0.044(0.0014-0.895)

- Multi-variate analysis revealed that gender and WSS were an independent predictors for the aneurysm with almost fully translucent wall.

Discussion

- Low WSS and higher pressure differential with respect to neck were independent factor of lower wall thickness.

  Kadashi LM et.al:J Neurosurg 119:172-9, 2013

- High pressure difference may be a key parameter for predicting thin-walled regions in unruptured cerebral aneurysms.

  Suzuki T et.al:Neurosurgery Epub ahead of print

Conclusion

- These findings strongly suggest that higher pressure may be useful to predict the thin-walled points within a cerebral aneurysm.
- Female and higher WSS can be an independent predictors for the cerebral aneurysms with almost fully translucent wall.
- CFD analysis might be very helpful to predict thin-walled points within unruptured cerebral aneurysms and also cerebral aneurysms with almost fully translucent wall. Therefore, CFD analysis would be one of useful tools to predict the subsequent rupture and determine surgical strategy in patients with unruptured aneurysms.