University of Groningen

Hemodynamics in the circle of Willis and prognostic factors in subarachnoid hemorrhage

Shen, Yuanyuan

DOI:
[10.33612/diss.192286680](https://doi.org/10.33612/diss.192286680)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):
Shen, Y. (2021). *Hemodynamics in the circle of Willis and prognostic factors in subarachnoid hemorrhage*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen.
<https://doi.org/10.33612/diss.192286680>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Hemodynamics in the circle of Willis and prognostic factors in subarachnoid hemorrhage

Yuanyuan Shen

Printing of this thesis was financially supported by the University of Groningen (RUG), University Medical Center Groningen (UMCG), Graduate School of Medical Science (GSMS), and the Research School of Behavioral and Cognitive Neurosciences (BCN).

The research reported in this dissertation was financially supported by the China Scholarship Council (CSC), the Chinese Ministry of Education.

Hemodynamics in the circle of Willis and prognostic factors in subarachnoid hemorrhage

PhD thesis

to obtain the degree of PhD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. C. Wijmenga
and in accordance with
the decision by the College of Deans.

This thesis will be defended in public on
Wednesday 1 December 2021 at 9.00 hours

by

Yuanyuan Shen

born on 29 September 1985
in HangZhou, China

Cover design: Edward Li, Anthony Cooper, Yuanyuan Shen

Layout and printing: Guus Gijben, Proefschrift-AIO | www.proefschrift-aio.nl

Copyright © 2021, Yuanyuan Shen, the Netherlands

All rights reserved. No part of this thesis may be produced, distributed, or transmitted in any form or by any means without the prior permission of the author or, where applicable, the publisher of the scientific papers.

Supervisor

Prof. J.M.C. van Dijk

Co-supervisors

Dr. M. Uyttenboogaart

Dr. R.P.H. Bokkers

Assessment Committee

Prof. J.A.M. Zeebregts

Prof. A. van der Zwan

Prof. W. van Zwam

Paranymphs

Sebastiaan Dulfer

Lilian M. Mennink

Dedicated to my family

PROPOSITIONS

accompanying the Phd thesis

Hemodynamics in the circle of Willis and prognostic factors in subarachnoid hemorrhage

1. The configuration of the circle of Willis influences the perfusion territories of cerebral feeding arteries and should therefore be considered in the management of carotid artery disease. (This thesis)
2. The global hemodynamic effect is a hemodynamic phenomenon in the circle of Willis, where each individual arterial segment in the circle of Willis has its own hemodynamic contribution to other segments and vice versa. (This thesis)
3. Hemodynamically, the configuration of the circle of Willis should be studied as a continuous variable rather than as a categorical variable. (This thesis)
4. When a numerical model of cerebral hemodynamics is applied in a clinical study, it is important that its measurement error is smaller than the minimal clinically important difference. (This thesis)
5. The proposed numerical model can reproduce the hemodynamics in the circle of Willis in both healthy people and in SAH-patients, but less accurate in SAH-patients who developed delayed cerebral ischemia. (This thesis)
6. In patients with SAH, myosteatosis is associated with higher WFNS grades at admission compared to patients without myosteatosis. (This thesis)
7. To be generally accepted, a system must be practical to use in a wide range of hospitals and by staff without special training. But the search for simplicity must not be the excuse for seeking absolute distinctions where none exist. (Graham Teasdale / Bryan Jennett)
8. Whenever you feel like criticizing anyone, just remember that all the people in this world haven't had the advantages that you've had. (F. Scott Fitzgerald, *The Great Gatsby*)
9. Constant dripping wears away a stone. (Idiom)
10. 长风破浪会有时, 直挂云帆济沧海。(李白)
A time will come to ride the wind and cleave the waves, I'll set my cloud-white sail and cross the sea which raves. (Li Bai)

Yuanyuan Shen

1 October 2021

TABLE OF CONTENT

Chapter 1

General introduction	11
----------------------	----

Chapter 2

Influence of the circle of Willis and carotid artery disease on the variability of the perfusion territories of the major cerebral arteries	29
---	----

Chapter 3

Study protocol of validating a numerical model to assess the blood flow in the circle of Willis	47
---	----

Chapter 4

Validating a numerical model to assess blood flow in the circle of Willis in patients with aneurysmal subarachnoid hemorrhage	61
---	----

Chapter 5

Simulated hemodynamics in the circle of Willis and intracranial aneurysms: a systematic review	86
--	----

Chapter 6

Skeletal muscle atrophy and myosteatosis are not related to long-term aneurysmal subarachnoid hemorrhage outcome	106
--	-----

Chapter 7

General discussion	129
--------------------	-----

Appendices

Nederlandse samenvatting	144
List of abbreviations	148
Acknowledgement	150
Curriculum vitae	153