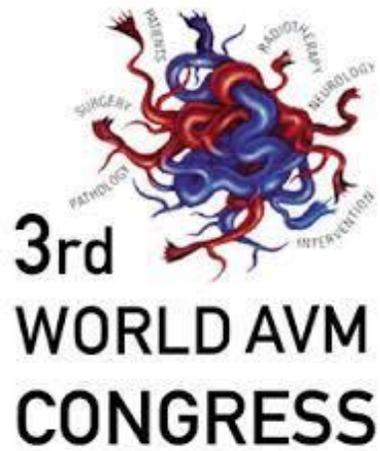
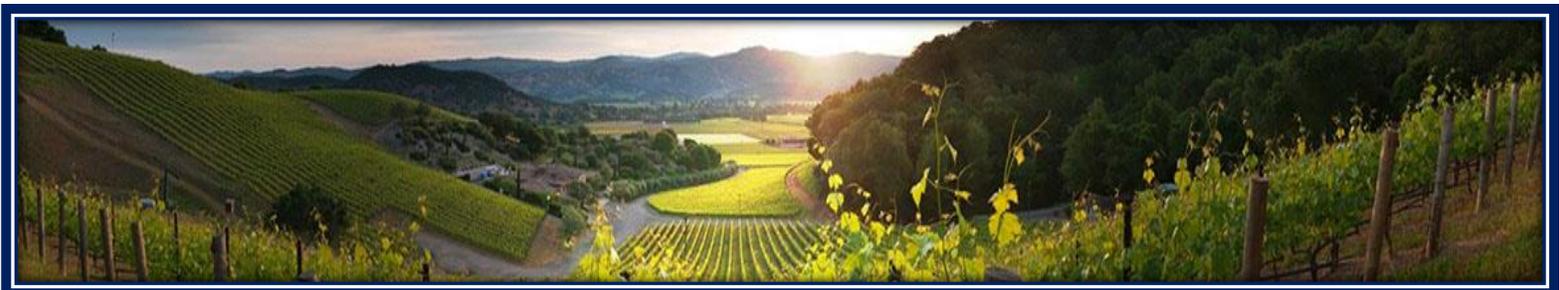


Final Program

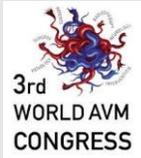


Napa, California

October 24-26, 2016



www.avmworldcongress.com



Scientific Committee

Felipe Albuquerque
Rustam Al-Shahi Salman
Sepideh Amin-Hanjani
Serge Bracard
Jan Burkhardt
Saruhan Cekirge
Steven D. Chang
Omar Choudhri
Ling Feng
Ioannis Fouyas
Peter Gooderham
Raphael Guzman
Michael Kelly
Douglas Kondziolka
Michael Lawton
Michael Marks
J P Mohr
Jacques Moret
Michael Morgan
Georges Rodesch
Gary Steinberg
Philipp Taussky

Organizing Committee

Omar Choudhri
Ann Crevelt
Faith Harding
Elizabeth Hoyt
Michael Lawton
Marco Lee
Cindy Samos
Gary Steinberg

Program Overview

Monday, 24 October

1:45PM	Opening Ceremony
2:00 – 2:00PM	Session 1: Basic Sciences/Pathologies
4:00 – 4:30PM	Break/Exhibit
4:30 – 6:00PM	Session II: Clinical Practice- World View
6:00 – 8:00PM	Welcome Reception (Taste of Napa)
8:00 – 9:00PM	Fireside Talk: Passage to Mars

Tuesday, 25 October

7:30 – 8:30AM	Breakfast
8:30 – 10:15AM	Session III: Pediatric Brain AVM
10:15 – 10:45AM	Break/Exhibit
10:45 – 12:30PM	Session IV: Brain AVM Surgery
12:30 – 1:30PM	Lunch/Exhibit
1:30 – 3:30PM	Session V: Brain AVM Endovascular
3:30 – 4:00PM	Break/Exhibit
4:00 – 6:00PM	Session VI: Brain AVM Radiosurgery
7:00PM	Banquet Dinner (Ticketed Event)

Wednesday, 26 October

7:30 – 8:30AM	Breakfast
8:30 – 10:30AM	Session VII: Spinal AVM
10:30 – 11:00AM	Break/Exhibit
11:00 – 12:55PM	Session VIII: Future Directions
12:55 – 1:00PM	Closing Ceremony Remarks
1:00PM	Lunch (Box Lunch to go)



Welcome

Dear Colleagues,

We are very excited that you have joined us at this meeting. The management of AVM continues to pose immense challenges for patients, care givers and all health providers involved in this condition. With the growth of knowledge and technological breakthroughs in this field, we are witnessing significant improvements in the clinical outcomes for our patients. However, this growth of information has not necessarily been accompanied by greater clarity in how best to manage this disease. As our experience in AVM management deepens, the controversies also broaden, not only between different disciplines but also within specialties.

The World AVM Congress provides a unique forum to learn about the latest research and explore the many controversies, with the common goal of providing the best care for our patients. We start the meeting with a session dedicated to the basic scientific research of AVMs, with a strong emphasis on the molecular etiology of the disease, exploring the contribution of cutting edge computational science in the study of AVMs and understanding the relevance of animal models.

The management of AVMs often varies depending on regional differences, which in itself may be driven by differences in healthcare systems, socio-economic factors or even cultural differences. A World-View session offers perspectives of AVM care from very varied regions, including China, Europe and the Sub-Saharan desert.

The main treatment modalities of Surgery, Endovascular Surgery and Radiosurgery will each have dedicated sessions, and insights into the interactions between these different modalities will be discussed. Much of the available research informs the management of adult brain AVMs and there's a relative paucity of information regarding Pediatric brain AVMs and spinal AVMs. Sessions dedicated to these entities will help address some of the differences in the management compared to adult brain AVMs.

The meeting ends with a session dedicated to looking forward into the future, always with the emphasis of how best to contribute scientifically in improving clinical outcome for our patients. In addition to individual speakers, there will be panel discussions and debates on controversial topics throughout the meeting. Common clinical cases will be presented that are encountered in everyday cerebrovascular practice. Debates between the panelists and audience on these and three controversial topics will for certain be highly informative, stimulating and entertaining.

Our scientific committee has also selected the best of all the submitted abstracts, which will be presented in both oral and e-poster forms during the meeting. In addition, two special talks will be both inspiring and educational. The San Francisco Bay area is home to many great institutions, including NASA Ames. Dr. Pascal Lee is a planetary scientist and has dedicated his career in preparing for a manned mission to Mars. We will hear his fascinating journey to making this bold goal a reality. Katherine and Ben Perreth are an amazing Mother and Son duo from Wisconsin, who has lived through firsthand all the tribulations of a ruptured cerebral AVM as a pediatric patient and a mother caring for her child. We are privileged to hear their personal story and perspective.

Thank you again for joining us at the 3rd World AVM Congress. It is harvest time in Napa and we look forward to seeing the many presentations, discussions and friendship bear fruit and generate a new crop of ideas.



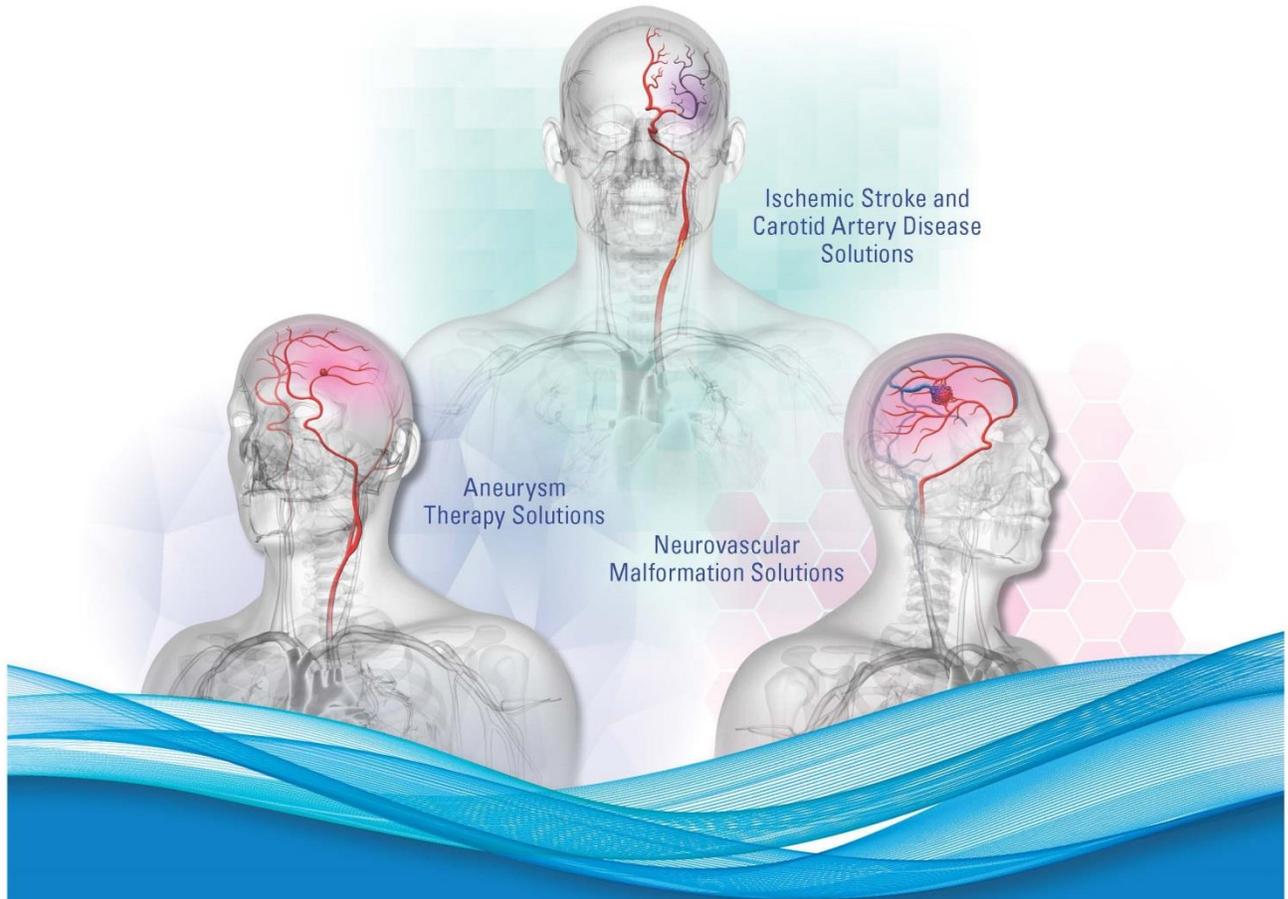
Meeting Co-Chairman
Gary K. Steinberg
Chairman,
Department of Neurosurgery
Stanford University
California, USA



Meeting co-chairman
Michael Lawton
Vice-Chairman,
Department of Neurological Surgery
University of California San Francisco
California, USA



*MicroVention® is a Proud Silver Sponsor of the
3rd World AVM Congress 2016*



A 360-Degree Approach to Performance Based Solutions

**Please visit our booth during the meeting to learn more about
MicroVention and our latest products.**

MICROVENTION is a registered trademark of MicroVention, Inc. Terumo is a registered trademark of Terumo Corporation.
© 2016 MicroVention, Inc.

Thanks to our Sponsors/Exhibitors

SILVER: MicroVention <http://www.microvention.com>

BRONZE: Balt International <http://www.balt.fr>

BRONZE: Medtronic <http://www.medtronic.com>

Accuray Inc. <http://www.accuray.com>

Aesculap <http://www.aesculapusa.com>

Carl Zeiss Meditech Inc. <http://www.meditec.zeiss.com/us>

Elekta <http://www.elekta.com>

Codman Neuro <http://www.codman.com>

Mizuho America, Inc. <http://www.mizuho.com>

Peter Lazic US, Inc. <http://www.peterlazic.com>

Siemens Medical Solutions <http://www.healthcare.siemens.com>

Surgical Theater <http://www.surgicaltheater.net>

The Aneurysm and AVM Foundation TAAF <http://www.taafonline.org>



Thank you for your valuable support

squid

The power of visibility,
the choice of fluidness



- Decreased density :
- to enable assessment of the AVM vasculature & the volume of liquid embolic injected.
- ↳ Lower radiopacity
- to avoid the over saturated radiopaque injected zones.
- Decreased viscosity :
- to enable deeper penetration into the nidus & to reach distal microvessels.

2L

SONIC

ALL REFERENCES OF SQUID CAN BE USED
WITH THE SONIC DETACHABLE TIP MICROCATETER
OR THE 12/12.6 GPO2 DOUBLE LUMEN MICROCATETER*

Decreased density	
SQUID18 SQUIDPERI 18	SQUID18LD SQUIDPERI 18LD
Decreased viscosity	
SQUID12 SQUIDPERI 12	SQUID12LD SQUIDPERI 12LD



SQUID is manufactured by EMBO-FLUESSIGKEITEN AG, Route des Aevullens 30, CH-1196 GLAND, Switzerland. * Not included in the package. The content of this document, in particular data, information, trademarks and logos are BALT INTERNATIONAL S.A.S and affiliates sole property. Consequently, all representation and/or reproduction, whether in part or in full, is forbidden and would be considered a violation of BALT INTERNATIONAL S.A.S and affiliates copyrights and other intellectual proprietary rights ©2016 BALT INTERNATIONAL S.A.S and affiliates all rights reserved. This document with associated pictures are non-contractual and are solely dedicated to healthcare professionals and BALT INTERNATIONAL S.A.S and supplier's distributors. The products shall exclusively be used in accordance with the package inserts which have been updated and included in the boxes. A002016004

Medtronic

Further, Together

Thank you for your valuable support



Special Guest Speakers

Pascal Lee, PhD

Chairman of the Mars Institute
Senior Planetary Scientist, SETI Institute
Director of NASA Haughton-Mars Project
NASA Ames Research Center
Moffett Field, California



MISSION: MARS Steps Toward the First Human Mission to the Red Planet

The first human mission to Mars will be humanity's greatest adventure in space exploration in the 21st century. As with all expeditions, its success will depend on planning. The first steps are already under way, as we achieve longer spaceflight missions, plan for deep space journeys to Near-Earth Asteroids, and explore extreme environments on Earth viewed as Mars "analogs". Dr Lee will discuss progress made around the world, from the Arctic to Antarctica, from basement labs to the International Space Station, to achieve the first human voyage to Mars. He will examine in turn the *what, why, how, when, and who* of the first human mission to Mars.

Dr Pascal Lee is a planetary scientist at the Mars Institute, the SETI Institute, and NASA Ames Research Center in Mountain View, California. He is internationally recognized for his work on the history of water on Mars, on the origin of Mars' moons, and on planning the future human exploration of Mars. Dr Lee has led over 30 expeditions to the Arctic and Antarctica to study Mars by comparison with the Earth. He recently led the Northwest Passage Drive Expedition, the subject of the documentary film *Passage To Mars* released in 2016. Dr Lee's first book, *Mission: Mars*, won the 2015 Prize for Excellence in children's science books from the American Association for the Advancement of Science. In his free time, he likes to be walked by his dogs, paint, and fly. He is a helicopter commercial pilot and flight instructor. He lives in Santa Clara, CA.

Katherine and Ben Perreth

Making Lemonade With Ben:
The Audacity to Cope



Humor. Hope. Information. Inspiration.

For three years, Wisconsin mother and son Katherine and Ben Perreth have been presenting aspects of Katherine's award-winning book, *Making Lemonade With Ben: The Audacity to Cope*.

Katherine holds University of Wisconsin-Madison Social Work and Sociology degrees. She conducts a class on reminiscence writing, is a freelance reporter, and works in an administrative role at an ESL school.

Ben, age 28, wears an ankle-foot-orthosis with a smiley face on the back. He juggles one-handed at the Madison Children's Museum and everywhere he goes in order to accomplish his life goal: "Make humanity smile."

Speakers

Felipe Albuquerque, MD

Endovascular Neurosurgeon
Barrow Neurological Institute
Phoenix, USA

Rustam Al-Shahi Salman, MA, PhD

Professor and Chair of Clinical Neurology
The University of Edinburgh
Edinburgh, UK

Serge Bracard, MD, PhD

Professor
University Hospital of Nancy
Nancy, France

Saruhan Cekirge, MD

Director of Interventional Neuroradiology
Bayindir Hospitals
Ankara, Turkey

Steve Chang, MD

Professor of Neurosurgery
Stanford University Medical Center
Stanford, USA

Marie Faughnan, MD, MSc

Associate Professor
University of Toronto
Toronto, Canada

Ioannis Fouyas, MD, PhD

Consultant Neurosurgeon
The University of Edinburgh
Edinburgh, UK

Haytham Hussein, MD

Neurosurgeon, Endovascular Neurosurgeon
NeuroSpine Center, Elribat University Hospital
Khartoum, Sudan

Helen Kim, MPH, PhD

Associate Professor
UCSF School of Medicine
San Francisco, USA

Douglas Kondziolka, MD

Professor, Neurosurgery & Radiation Oncology
NYU Langone Medical Center
New York, USA

Michael Lawton, MD

Professor and Vice Chair of Neurological Surgery
University of California, San Francisco
San Francisco, USA

Pascal Lee, PhD

Chairman of the Mars Institute
Director of NASA Haughton-Mars Project
NASA Ames Research Center, Moffett Field, USA

Dean Li, MD, PhD

Professor of Medicine
University of Utah
Salt Lake City, USA

Michael Marks, MD

Professor and Chief, Interventional Neuroradiology
Stanford University Medical Center
Stanford, USA

Michael McDermott, MD

Professor and Vice Chairman, Neurological Surgery
University of California, San Francisco
San Francisco, USA

Phil Meyers, MD

Professor, Radiology and Neurological Surgery
Columbia University Medical Center
New York, USA

Jay P Mohr, MD

Professor of Neurology
New York Presbyterian/Columbia University
New York, USA

Jacques Moret, MD, PhD

Professor and Chairman, Interventional Radiology
Beaujon University Hospital
Clichy, Paris, France

Speakers

Michael Morgan, MD, PhD

Professor, Neurosurgery
Macquarie University Hospital
Sydney, Australia

Darren Orbach, MD, PhD

Division Chief, Neurointerventional Radiology
Boston Children's Hospital
Boston, USA

Kathrine and Ben Perreth

Parent and Patient
Freelance Reporter
Wisconsin, USA

Jean Raymond, MD

Professor, Interventional Neuroradiology
Université de Montréal
Montreal, Quebec, Canada

Howard A. Riina, MD, MPH

Professor of Neurosurgery
NYU Langone Medical Center
New York, USA

Georges Rodesch, MD

Head, Dept. of Diagnostic & Therapeutic
Neuroradiology
Hôpital Foch
Paris, France

Laligham Sehkhari, MD

Professor and Vice Chair, Neurological Surgery
University of Washington, School of Medicine
Seattle, USA

Gary K. Steinberg, MD, PhD

Professor and Chair, Dept. of Neurosurgery
Stanford University Medical Center
Stanford, USA

Hua Su, MD

Professor of Anesthesia
University of California, San Francisco
San Francisco, USA

Joseph Sullivan, MD

Associate Professor, Neurology
University of California, San Francisco
San Francisco, USA

Ulrich Sure, MD

Chairman, Department of Neurosurgery
University Hospital Essen
Essen, Germany

Miikka Vakkula, MD, PhD

Professor of Human Genetics
de Duve Institute, University of Louvain
Brussels, Belgium

Reinhard E. Wurm, MD

Chief Physician
Radiation Therapy and Radiooncology
Clinic Frankfurt (Oder) GmbH
Brandenburg, Germany

Hong-Qi Zhang, MD

Professor, Director of Spinal Surgery
Xiangya Hospital Central South University
Beijing, China

Yuanli Zhao, MD

Professor, Department of Neurosurgery
Beijing Tiantan Hospital
Beijing, China

Monday, 24 October PM

9:00 AM – onward Registration

1:45 PM Opening Ceremony

2:00-4:00 Session 1: Basic Sciences/Pathogenesis

Moderator: Michael Lawton

- 2:00-2:20 Exploiting machine learning and artificial intelligence to the study of vascular anomalies and other genetic diseases.
DEAN LI (Salt Lake City, USA)
- 2:20-2:40 Etiological insights from genetics of AVM.
MIIKKA VIKKULA (Brussels, Belgium)
- 2:40-3:00 Identifying therapeutic targets using brain AVM animal models.
HUA SU (San Francisco, USA)
- 3:00-3:20 Genome wide association studies in sporadic brain AVM
HELEN KIM (San Francisco, USA)
- 3:20-3:30 Thalidomide and Lenalidomide treatment stabilizes the vascular wall and reduces microhemorrhage in mouse brain AVM.
WAN ZHU (San Francisco, USA)
- 3:30-3:40 Hedgehog signaling in human brain AVMs.
ROBERTO POLA (Boston, USA)
- 3:40-3:50 Alk1 deficiency in bone marrow-derived endothelial cells leads to AVMs.
QUIANG LI (San Francisco, USA)
- 3:50-4:00 Nitric oxide synthase inhibition attenuates the formation of notch-mediated brain AVM.
RONG WANG (San Francisco, USA)

4:00-4:30 Break/Exhibit

Medtronic
Further, Together

4:30-6:00 Session II: Clinical Practice-World View

Moderator: Robert Dodd

- 4:30-4:50 Contrasts on AVM management in China with the world.
YUANLI ZHAO (Beijing, China)
- 4:50-5:10 A global view of the outcome for people with untreated brain AVMs.
RUSTAM AL-SHAHI SALMAN (Edinburgh, UK)
- 5:10-5:20 Treatment of AVM in Sudan.
HAYTHAM HUSSEIN (Khartoum, Sudan)
- 5:20-5:55 Consult the Experts: Multi-disciplinary panel discussing on COMMON cases
Serge Bracard, Saruhan Cekirge, Jay P Mohr, Laligham Sehkhari, Michael Marks, Gary Steinberg
- 5:55-6:00 Day 1 Closing Remarks
- 6.00-8.00 Welcome Reception: Taste of Napa**
- 8:00-9:00 Fireside Talk: Passage to Mars**
PASCAL LEE (NASA Ames, USA)

Tuesday, 25 October AM

7:30-8:30 Breakfast

8:30-10:15 Session III: Pediatric Brain AVM

Moderator: Raphael Guzman

- 8:30-8:50 Unruptured brain AVM in the pediatric population.
DARREN ORBACH (Boston, USA)
- 8:50-9:10 Management of seizures associated with AVM in the pediatric population.
JOSEPH SULLIVAN (San Francisco, USA)

- 9:10-9:30 AVM associated syndromes.
MARIE FAUGHNAN (Toronto, Canada)
- 9:30-9:40 AVMs at a rare anatomic and developmental interface.
OMAR CHOUDHRI (San Francisco, USA)
- 9:40-9:50 Multimodality management of Spetzler-Martin Grade 3 brain arteriovenous malformations with subgroup analysis.
ISAAC J. ABECASSIS (Seattle, US)
- 9:50-10:15 Twenty years living with a veritable mess: Spetzler-Martin grade 4 hemorrhage, craniotomy & proton beams (parent and patient perspective)
KATHERINE and BEN PERRETH (Wisconsin, USA)

Introduction: Mary Marcellus

10:15-10:45 Break/Exhibit

10:45-12:30 Session IV: Brain AVM Surgery

Moderator: David Langer

- 10:45-11:05 How and why my practice changed after ARUBA - a neurosurgeon's perspective.
IOANNIS FOUYAS (Edinburgh, UK)
- 11:05-11:25 Surgical treatment of AVM after radiosurgery.
GARY K. STEINBERG (Stanford, USA)
- 11:25-11:45 Role of embolization before surgery.
MICHAEL MORGAN (Sydney, Australia)
- 11:45-12:05 Surgical treatment of brain AVM.
MICHAEL LAWTON (San Francisco, USA)
- 12:05-12:15 Surgical management of low-grade unruptured brain arteriovenous malformations in non-neurologically impaired patients.
EDUARDO MARTINEZ-DEL-CAMPO (Phoenix, USA)
- 12:15-12:30 How I would do it differently?
LALIGHAM SEHKHAR (Seattle, USA)

12:30-1:30 Lunch/Exhibit

Tuesday, 25 October PM

1:30-3:30 Session V: Brain AVM Endovascular



Moderator: Philip Tausky

- 1:30-1:50 Indications of embolization prior to AVM surgery.
PHIL MEYERS (Columbia, USA)
- 1:50-2:10 How do associated aneurysms change AVM management?
ULRICH SURE (Essen, Germany)
- 2:10-2:30 Is there a role of pre-radiosurgical embolization of AVM?
MICHAEL MARKS (Stanford, USA)
- 2:30-2:45 How I would do it differently?
SERGE BRACARD (Nancy, France)
- 2:45-3:30 **Debate.** Motion: The first line approach with the goal of curative treatment of grade 1-2 AVM should now be endovascular.

3:30-4:00 Break/Exhibit



4:00-6:00 Session VI: Brain AVM Radiosurgery

Moderator: Steven Chang

- 4:00-4:20 Hypofractionated or staged compartment radiosurgery treatment in large AVMs?
REINHARD WURM (Berlin, Germany)
- 4:20-4:40 Volume staged radiosurgery for large AVMs.
MICHAEL McDERMOTT (San Francisco, USA)
- 4:40-4:50 Arterial-spin labeling for the non-invasion follow-up of cerebral AVMs following stereotactic radiosurgery treatment.
NEIL THAKUR (Stanford, USA)

4:50-5:00 Higher flow is present in unruptured arteriovenous malformations with silent microhemorrhage.
XIAOLIN CHEN (San Francisco, USA)

5:00-5:15 How I would do it differently?
DOUGLAS KONDZIOLKA (New York, USA)

5:15-6:00 **Debate.** Motion: Radiosurgery rather than surgery is the treatment of choice in grade 1-2 AVMs.

7:00 Banquet Dinner (Ticketed Event)

Wednesday, 26 October AM

7:30-8:30 Breakfast

8:30-10:30 Session VII: Spinal AVM

Moderator: Michael Marks

8:30-8:50 Natural history of spinal cord AVMs.
GEORGES (Paris, France)

8:50-9:10 Endovascular treatment of spinal AVM.
FELIPE ALBUQUERQUE (Phoenix, USA)

9:10-9:30 Surgical treatment of spinal AVM.
ZHANG HONGQI (Beijing, China)

9:30-9:50 Radiosurgical treatment of spinal AVM.
STEVEN D. CHANG (Stanford, USA)

9:50-10:00 Cyberknife radiosurgery for spinal cord AVMs.
ERIC S. SUSSMAN (Stanford, USA)

10:00-10:10 The study on the treatment of brain AVMs (TOBAS): Feasibility of a randomized controlled care trial and registry
ELSA MAGRO (Brest, France)

Program

10:10-10:25 How I would do it differently?
HOWARD A. RIINA (New York, USA)

10:25-10:30 Announcements

10.30-11.00 Break/Exhibit

11:00-1:00 Session VIII: Future Directions

Moderator: Gary Steinberg

11:00-11:20 Future Directions for the Management of Brain AVMs.
MICHAEL LAWTON (San Francisco, USA)

11:20-11:40 Transvenous or transarterial approach to AVMs?
JACQUES MORET (Paris, France)

11:40-12:00 Trials integrated to care: the treatment of brain AVM study (TOBAS).
JEAN RAYMOND (Montreal, Canada)

12:00-12.45 **Debate.** Motion: More randomized trials involving people with brain AVMs are needed.

12:45-12.55 Open Forum: Have your say

12.55-1.00 Closing Ceremony and Remarks

1:00PM Lunch (Box Lunch to go)



ABSTRACTS/ORAL PRESENTATIONS

3:20 PM - 3:30 PM

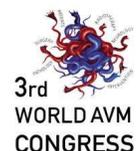
Thalidomide and Lenalidomide Treatment Stabilizes the Vascular Wall and Reduces Microhemorrhage in Mouse Brain Arteriovenous Malformations Reduces Microhemorrhage in Mouse Brain Arteriovenous Malformations

Wan Zhu¹, Dingquan Zhu¹, Wanqiu Chen¹, Bao Chen¹, Rui Zhang¹, Lei Zhan¹, Meng Zhang¹, Ethan Winkler², Michael Lawton², **Hua Su, MD¹**.

¹Anesthesia, University of California, San Francisco, San Francisco, CA, USA, ²Neurosurgery, University of California, San Francisco, San Francisco, CA, USA.

Objective: Brain arteriovenous malformations (bAVMs) have an abnormal vascular wall that is prone to rupture. The mechanisms underlying bAVM disruption remain unclear. A subset of bAVMs is associated with mutations of activin-like kinase 1 (*ALK1*) gene. In *Alk1*-deficient mice, bAVM vessels have less mural cells. Thalidomide increases mural cells of retina AVM vessels in endoglin (another AVM causative gene) deficient mice. We hypothesize that thalidomide and its less toxic analogue, lenalidomide improves vessels mural cell-coverage and reduces microhemorrhage in *Alk1* deficient bAVM. **Methods:** *Alk1*^{2f/2f} mice were intra-brain injected with Ad-Cre and AAV1-VEGF to induce bAVM. Thalidomide (1.88mg/25g) were injected intraperitoneally twice per week for six weeks starting either 2 weeks after model induction when bAVMs were starting to develop or 8 weeks after model induction when bAVMs were fully developed. Lenalidomide (1.25mg/25g) treatment was started 8 weeks after model induction through intraperitoneal injection daily for six weeks. **Results:** Thalidomide treatment starting 2 weeks after the bAVM induction reduced the number of abnormal vessels ($p=0.001$) and microhemorrhage detected by Prussian blue staining ($p=0.001$). This was associated with an increase of vascular smooth muscle coverage ($p=0.03$). Thalidomide have also increased the expression of platelet derived growth factor b (pdgfb) and its receptor (pdgfr beta), indicating that pdgfg/pdgfr beta signaling pathway is one of the underlining mechanisms responsible to the improvement of mural cell-coverage after thalidomide treatment. Thalidomide and lenalidomide treatments started at the later time point when the bAVMs were fully formed also improved smooth muscle coverage and a trend of reduction of the number of abnormal vessels and microhemorrhage in bAVMs. **Conclusions:** Thalidomide and its less toxic derivative, lenalidomide, stabilize bAVM vessel wall by increase mural cell-coverage and reduce microhemorrhage. Further studies are indicated to determine whether these agents have therapeutic value in patients.

24-26 October 2016
Napa, California



ABSTRACTS/ORAL PRESENTATIONS

3:30 PM - 3:40 PM

Hedgehog Signaling in Human Brain AVMs

Roberto Pola, MD PhD¹, Carmelo Sturiale², Igor Giarretta³, Eleonora Gaetani³, Ilaria Gatto⁴, Alfredo Puca².

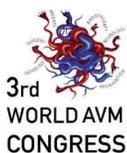
¹Medicine, Tufts University, Boston, MA, USA, ²Neurosurgery, A. Gemelli University Hospital, Rome, Italy, ³Medicine, A. Gemelli University Hospital, Rome, Italy, ⁴Medicine, Catholic University School of Medicine, Rome, Italy.

INTRODUCTION/PURPOSE: Hedgehog (HH) proteins are morphogens with an important role in angiogenesis and vascular development. In this study, we investigated the expression of the HH signaling pathway in human AVMs. We also evaluated the hypothesis that an angiogenic growth that displays the characteristic features of AVMs may be obtained by activating the HH signaling.

METHODS: The expression of the HH pathway was analyzed in ten specimens of human AVMs and ten specimens of human normal brain by real-time RT-PCR and immunofluorescent staining. The possibility to induce the growth of an arteriovenous angiogenic process by activating the HH pathway was tested in ephrinB2-lacZ mice, which carry the lacZ reporter gene under the control of the promoter of the ephrinB2 gene, which is specifically expressed in arteries but not in veins. Pellets containing SHH were implanted into the cornea of these mice and the resulting angiogenic process was studied.

RESULTS: Among the various components of the HH pathway, the HH inhibitory protein HHIP was significantly and constantly down-regulated in all human brain AVM specimens, compared to controls. Immunofluorescence revealed SHH expression on endothelium of AVMs, while no positive staining for SHH was observed in the endothelium of normal brain. Likewise, Gli-1 - the major transcription factor of the HH pathway - was expressed in the endothelium of brain AVMs but not in the endothelium of normal brain. When pellets containing SHH were implanted into the cornea of ephrinB2-lacZ mice, the resulting angiogenic process was characterized by the growth of both arterial and venous vessels, interconnected by complex sets of arteriovenous shunts without an interposed capillary bed, as seen in AVMs in humans.

CONCLUSIONS: This is the first demonstration of the activation of the HH pathway in human AVMs.



3rd
WORLD AVM
CONGRESS 24-26 October 2016
Napa, California

ABSTRACTS/ORAL PRESENTATIONS

3:40 PM - 3:50 PM

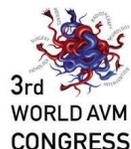
Alk1 Deficiency in Bone Marrow-Derived Endothelial Cells Leads to Arteriovenous Malformations

Man Luo¹, Qiang Li², Li Ma¹, Rui Zhang¹, Lei Zhan¹, Michael Lawton², **Hua Su, MD¹**.

¹Anesthesia, University of California, San Francisco, San Francisco, CA, USA, ²Neurosurgery, University of California, San Francisco, San Francisco, CA, USA.

Background and Purpose: In humans, activin receptor-like kinase 1 (Alk1) deficiency causes arteriovenous malformations (AVMs) in multiple organs, including the brain and the intestine. We previously found induction of endothelial deletion of *Alk1* in adult mice leads to AVM formation in multiple organs and the brain angiogenic region and endoglin deficient bone marrow (BM) can transmit abnormal brain vascular phenotype to wild-type (WT) mice. We hypothesize that *Alk1* deletion in BM-derived endothelial cells (BMDECs) is sufficient to induce AVMs in the adult mice. **Methods:** *Alk1*^{2f/2f} mice (*Alk1* exons 4-6 flanked by loxP sites) were bred with *pdgfb*-iCreER transgenic mice that express tamoxifen (TM)-inducible cre recombinase (iCreER) in the endothelial cells to produce *pdgfb*-iCreER;*Alk1*^{2f/2f} mice. BM isolated from adult *pdgfb*-iCreER;*Alk1*^{2f/2f} mice were transplanted to lethally irradiated 8 weeks-old WT mice. An adeno-associated viral vector expressing VEGF (AAV-VEGF) was injected into the brain 4 weeks after the BM-transplantation. Two weeks later, *Alk1* deletion was induced by intra-peritoneal injection of TM (2.5 mg/20g body weight). Vascular morphology was analyzed using latex casting 6 weeks after TM administration. Due to the particle size, latex inters vein after intra-cardiac left ventricle injection only when there is arteriovenous shunt, an important phenotype of AVM. **Results:** Peripheral blood cell-counts were fully recovered in the recipients 4 week after BM-transplantation. The mice transplanted with *pdgfb*-iCreER;*Alk1*^{2f/2f} BM developed AVMs in the intestine and the brain angiogenic region after TM treatment. Intestinal bleeding was evidenced by the presence of darkened feces. Unlike *pdgfb*-iCreER;*Alk1*^{2f/2f} mice that will die in 2 weeks after TM treatment, mice with *pdgfb*-iCreER;*Alk1*^{2f/2f} BM did not die within 6 weeks after TM treatment, suggesting that their intestinal AVMs were less severe than those in *pdgfb*-iCreER;*Alk1*^{2f/2f} mice. **Conclusion:** *Alk1* deficiency in BMDECs is sufficient to induce AVMs in multi-organ, including the brain angiogenic region.

24-26 October 2016
Napa, California



ABSTRACTS/ORAL PRESENTATIONS

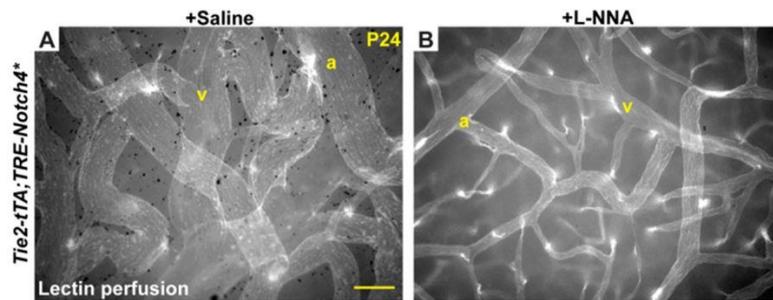
3:50 PM - 4:00 PM

Nitric Oxide Synthase Inhibition Attenuates the Formation of Notch-Mediated Brain Arteriovenous Malformation

Rong Wang, -, L Huang.

Surgery, UCSF, San Francisco, CA, USA.

Introduction: Notch is distinctively expressed in arterial but not venous endothelial cells. Notch signaling regulates arteriovenous (AV) specification. Endothelial expression of constitutively active Notch4 (Notch4^{*}) initiates brain AVMs in mice through enlargement of microvessels, raising the possibility that enhanced vasodilation may play a role in initiation of AV shunting. We hypothesized that Notch4^{*} disrupts nitric oxide (NO) signaling, thereby permitting vessel enlargement and AV shunting. **Methods:** Pharmacological inhibition of NO synthase (NOS) by administering the NOS inhibitor N^G-nitro-L-arginine or genetic deletion of endothelial NOS (eNOS) in Notch4^{*} brain AVM mouse model. **Results:** Both approaches attenuated Notch4^{*}-mediated brain AVM formation, as measured by decreased AV shunt diameter, and improved survival of Notch4^{*} mice while reduced severity of brain AVM-associated pathologies. Our results show that inhibiting NOS/eNOS signaling reduced Notch4^{*}-mediated brain AVM formation and suggest that targeting NOS/eNOS pathway may be a potential strategy to retreat Brain AVMs.



L-NNA treatment attenuated brain AV shunt formation in Notch4^{*} mice.



3rd
WORLD AVM CONGRESS 24-26 October 2016
Napa, California

ABSTRACTS/ORAL PRESENTATIONS

9:30 AM - 9:40 AM

A Supplementary Grading Scale Combining Lesion to Eloquence Distance for Predicting Surgical Outcomes of Patients with Brain Arteriovenous Malformations

Yong Cao, MD.

Beijing Tiantan Hospital, Capital Medical University, Beijing, China.

Object: This study aimed to construct a predictive grading system combining lesion to eloquence distance (LED) for selecting patients with BAVMs for Surgery. **Methods:** From September 2012 and Sep 2015, we retrospectively studied 201 consecutive patients with BAVMs. All patients undergone preoperative functional MRI (fMRI), and diffusion tensor imaging (DTI), followed by resection. Both angioarchitectural factors and LED were analyzed with respect to the change between preoperative and final postoperative Modified Rankin Scale (MRS) scores. LED refers to distance between lesion and the nearest eloquence (eloquent cortex or fiber tracts) measured by preoperative fMRI and DTI. We constructed three new grading systems: HDVL included the independent predictors of MRS change (hemorrhagic presentation, diffuseness, deep venous drainage and LED); Full Score combined variables in Spetzler-Martin (S-M) and HDVL. We added the consideration of involving of eloquent fiber tracts to SM grading system and developed the fSM grading system. The area under the receiver operating characteristic (ROC) curves (AUROC) were compared. **Results:** LED was significantly correlated with change in MRS score ($p < 0.001$). Predictive accuracy was highest for the HDVL grading system (AUROC, 0.82), followed by the Full Score grading system (0.80), the fSM grading system (0.79) and least for the S-M grading system (0.71). Predictive accuracy of the HDVL grading system was significantly better than that of the Spetzler-Martin grade ($p = 0.040$). **Conclusion** LED was a significant predictor for the preoperative risk evaluation for surgery. The HDVL system is a good predictive grading system of neurological outcomes after BAVM surgery. Adding consideration of the involving of eloquent fiber tracts to preoperative evaluation can effectively improve the predictive accuracy.

24-26 October 2016
Napa, California



ABSTRACTS/ORAL PRESENTATIONS

9:40 AM - 9:50 AM

Multimodality Management of Spetzler-Martin Grade 3 Brain Arteriovenous Malformations with Subgroup Analysis

Isaac J. Abecassis, MD, John D. Nerva, Abdullah Feroze, Jason Barber, Jason Rockhill, Louis J. Kim, Laligam Sekhar.

Neurological Surgery, University of Washington, Seattle, WA, USA.

INTRODUCTION/PURPOSE: Spetzler-Martin grade 3 (SMIII) lesions are particularly variable in behavior management, with 4 distinct subtypes described based on size, eloquence, and deep venous drainage (DVD) (IIIA, IIIB, IIIC, and IIID). The results of A Randomized Trial of Unruptured Brain AVMs (ARUBA) introduced additional controversy and attention towards management strategies of unruptured bAVMs (UbAVMs) in general, despite a small representation of SMIII lesions.

METHODS: We retrospectively reviewed 135 patients with treated SMIII bAVMs, including both ruptured and unruptured. Lesions were classified into 1 of the 4 previously described subtypes. Primary outcomes included modified Rankin score (mRS) at most recent follow-up, mortality, and bAVM recurrence or rebleed. For UbAVMs, an “ARUBA eligible” subgroup analysis (i.e. mRS less than or equal to 1) was performed. Statistical analysis was performed. We also reviewed the literature on management of both SMIII UbAVMs and RbAVMs.

RESULTS: Of the 135 identified SMIII bAVMs, 40 percent were unruptured. Average follow up was 2.7 years in the UbAVMs and 2.0 years in RbAVMs. Most lesions in the UbAVM group were IIIC (44%) and IIIA (33%), compared to IIIA (70%) in the RbAVM group. Average mRS at presentation was 0.8 for UbAVM and 2.8 for RbAVM. UbAVM IIIA underwent either surgical resection with preoperative embolization (42%) or gamma knife (58%); IIIC were most likely to undergo multimodality therapy (surgery, embolization, and gamma knife). mRS at most recent follow up was 1.3 for UbAVM and 1.8 for RbAVM; there were no statistical differences amongst type III AVM subtypes. Similarly, there were no significant differences amongst rates of complication, transient, and persistent neurological deficits.

CONCLUSIONS: Despite differences in angioarchitecture and anatomy, type III AVMs can be treated effectively with multimodality therapies including surgery, embolization, and gamma knife therapy, regardless of subtype. Outcomes are similar, in both ruptured and unruptured groups.



3rd
WORLD AVM CONGRESS 24-26 October 2016
Napa, California

ABSTRACTS/ORAL PRESENTATIONS

12:05 PM - 12:15 PM

Surgical Management of Low-Grade Unruptured Brain Arteriovenous Malformations in Non Neurologically Impaired Patients

Eduardo Martinez-del-Campo, MD, Karam Moon, Peter Nakaji, Felipe C. Albuquerque, Cameron G. McDougall, Robert F. Spetzler, Joseph M. Zabramski.
Neurological Surgery, Barrow Brain and Spine, Phoenix, AZ, USA.

INTRODUCTION: Surgical resection of low-grade (Spetzler-Martin grades I-II) bAVMs remains common, and is associated with low mortality and morbidity rates, and high cure rates. We hypothesized that a study of surgical treatment in a subgroup of neurologically intact patients (modified Rankin Scale scores of 0 - 1 [non-impaired]) would allow the most accurate assessment of effects of surgery for obliteration of low-grade bAVMs.

METHODS: A retrospective review of all surgical resections, with or without embolization, for an unruptured low-grade bAVMs in neurologically intact patients with only headache and seizures. The primary endpoint was the same as ARUBA.

RESULTS: Sixty-one patients were included for analysis. There were 54.1% females, mean age and follow-up of 38.2 years and 39.8 months, respectively. All patients were radiographically cured after surgery, with no recurrences or deaths. No patients reached the primary outcome. After surgery, 14/61 (22.4%) patients had neurological deficits versus only 5/61 (8.2%) patients at last follow-up. Half of the patients were asymptomatic at last follow-up versus to 8/61 (13.1%) at presentation ($P < .01$). Seizures completely resolved in 60.7% of patients (17/28). There were no major strokes, deaths, or severe impairments. The overall rate of long-term neurologic complications and clinical impairment was 1/61 (1.6%). The perioperative and postembolization complication rate was 6.6% (4/61) and 10% (3/30), respectively.

CONCLUSION: Surgical resection of unruptured low-grade bAVMS in non-impaired patients is safe and results in a low rate of clinical deterioration in experienced hands.

New neurologic deficits after surgery of unruptured bAVMs in 61 intact patients

Deficit	Pre-op n(%)	Last FU n(%)	P value
Visual field loss	4 (6.6)	3 (4.9)	>.99
Hemiparesis	2 (3.3)	0 (0.0)	.50
Partial seizures	0 (0.0)	1 (1.6)	.49
Mild aphasia	6 (9.8)	1 (1.6)	.12
Ophthalmoplegia	1 (1.6)	0 (0.0)	>.99
Dysmetria	1 (1.6)	0 (0.0)	>.99

ABSTRACTS/ORAL PRESENTATIONS

4:40 PM - 4:50 PM

Arterial-Spin Labeling for the Non-Invasive Follow-Up of Cerebral AVMs Following Stereotactic Radiosurgery Treatment

Neil Thakur¹, Gregory Zaharchuk¹, Michael Iv¹, Nancy Fischbein¹, **Jeremy Heit, MD, PhD²**.

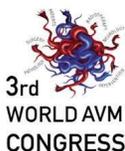
¹Diagnostic Neuroradiology, Stanford University, Stanford, CA, USA, ²Neurointerventional Radiology, Stanford University, Stanford, CA, USA.

INTRODUCTION/PURPOSE: Long-term imaging followup is needed to ensure complete brain AVM obliteration is obtained after stereotactic radiosurgery (SRS). DSA remains the gold standard in assessment, but carries procedural risks and is relatively costly. Conventional MRI/MRA sequences are predictive in evaluating for AVM obliteration post-SRS, but with sensitivity and specificity inferior to DSA. Arterial spin labeling(ASL) is a noncontrast MRI sequence shown to be sensitive in the detection of arteriovenous shunting. The purpose of this study was to determine the sensitivity and specificity of ASL in the detection of residual AVMs post-SRS, using DSA as the reference.

METHODS: We retrospectively reviewed and identified all patients who had undergone DSA for AVM evaluation from 6/2010-6/2015. Patients met inclusion criteria if they 1) had undergone SRS for brain AVM, 2) had a followup MRI with ASL at least 30 months post-SRS, 3) had a DSA within 3 months of the follow up MRI with ASL, and 4) had no intervening AVM treatment between the MRI and DSA. Four neuroradiologists independently reviewed MRIs for abnormal venous ASL signal suggestive of arteriovenous shunting. Reviewers were blinded to the results of the follow up DSA, which was independently and blindly reviewed by an interventional neuroradiologist.

RESULTS: 15 patients met inclusion criteria. DSA demonstrated complete AVM obliteration in 5, and residual AVM in 10 patients. The sensitivity and specificity of venous ASL signal for predicting residual AVM on followup DSA was 100% and 95%, respectively. Interobserver agreement was 0.92.

CONCLUSIONS: ASL with abnormal venous signal is highly accurate in identifying residual AVM post-SRS treatment, with sensitivity and specificity approaching that of DSA. Given the improved accuracy over conventional MRI sequences, ASL should be included in all MRI studies evaluating AVMs post-SRS. Future studies should investigate whether MRI with ASL may be used to triage patients to DSA to guide additional AVM treatment.



3rd
WORLD AVM
CONGRESS

24-26 October 2016
Napa, California

ABSTRACTS/ORAL PRESENTATIONS

4:50 PM - 5:00 PM

Higher Flow Is Present in Unruptured Arteriovenous Malformations with Silent Microhemorrhage

Xiaolin Chen, MD, PhD¹, Daniel Cooke², David Saloner³, Jeff Nelson¹, Hua Su¹, Michael Lawton⁴, Christopher Hess⁵, Tarik Tihan⁶, Yuanli Zhao⁷, Helen Kim¹.

¹Anesthesia and Perioperative Care, Center for Cerebrovascular Research, University of California, San Francisco, San Francisco, CA, USA, ²Department of Radiology, Neurology and Neurological Surgery, University of California, San Francisco, San Francisco, CA, USA, ³Department of Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, CA, USA, ⁴Department of Neurological Surgery, University of California, San Francisco, San Francisco, CA, USA, ⁵Department of Radiology, University of California, San Francisco, San Francisco, CA, USA, ⁶Department of Pathology, University of California, San Francisco, San Francisco, CA, USA, ⁷Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, Beijing, China.

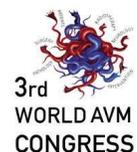
INTRODUCTION: Evidence of temporally remote and clinically occult hemorrhage (hemosiderin) has been observed in resected tissue from cerebral arteriovenous malformations (AVMs), and may represent a subgroup at increased risk for clinical hemorrhage. Previous studies suggest that ruptured AVMs having faster flow and shorter mean transit time (MTT) of contrast in blood vessels than unruptured AVMs. We hypothesized that the hemodynamic flow patterns of unruptured AVMs with evidence of hemosiderin have similar features to those of ruptured AVMs.

METHODS: We selected unruptured, supratentorial AVMs >3.5cc with pathology specimens available from the UCSF Brain AVM Study database. Hemodynamic features were evaluated using Siemens syngo iFlow color coding angiography, including contrast mean transit time (MTT) of the largest feeding artery, longest draining vein, through the AVM nidus, and the ratio (MTT drainer/MTT feeder). Hemodynamic and angioarchitectural characteristics were compared between 9 unruptured AVMs with hemosiderin and 16 without hemosiderin using t-test and Fisher's exact test.

RESULTS: The MTT of feeding artery and draining vein did not differ significantly between groups. However, there was a significant difference in MTT through the AVM nidus, with shorter MTT in AVMs with hemosiderin compared to those without hemosiderin (1.11 ± 0.28 seconds versus 1.64 ± 0.55 ; $P=0.013$). A lower ratio of MTT of the drainer to feeder (1.47 ± 0.31 versus 1.93 ± 0.6 ; $P=0.04$) was also observed. Clinical presentation, location of AVMs, larger feeding artery, presence of flow-related aneurysm, and number of draining veins were not significantly different between the two groups. Presence of venous varix was significantly associated with hemosiderin ($p=0.003$).

CONCLUSIONS: The shorter contrast MTT through AVM nidus, lower ratio of MTT of drainer to feeder, and higher prevalence of venous varix in unruptured AVMs with evidence of hemosiderin suggests a high-flow in this subtype.

24-26 October 2016
Napa, California



ABSTRACTS/ORAL PRESENTATIONS

9:50 AM - 10:00 AM

CyberKnife Radiosurgery for Spinal Cord AVMs

Eric S. Sussman, MD, John R. Adler, Robert L. Dodd.

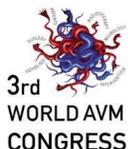
Neurosurgery, Stanford University, Palo Alto, CA, USA.

Introduction: Spinal cord arteriovenous malformations (SCAVMs) are rare entities that account for less than 20% of spinal masses. These lesions represent a unique clinical challenge, in that surgical or endovascular treatment is often associated with devastating functional consequences. Here, we present our experience in treating such lesions with CyberKnife Radiosurgery (CKRS).

Methods: Forty (40) patients with SCAVMs received CKRS at Stanford Medical Center between 1997 and 2014, and were enrolled in this prospective study. The particular radiosurgical treatment regimen was tailored to each individual patient, and evolved over the course of the study as we gained experience treating these lesions with CKRS. Clinical and magnetic radiographic imaging (MRI) follow up were obtained at 6-months, 1-year, and annually thereafter. Spinal angiogram was obtained at three years following treatment, or after MRI revealed absence of flow voids, whichever came sooner.

Results: Nineteen (19) patients (47.5%) received other treatment of their SCAVMs prior to CKRS (3 surgical, 11 endovascular, and 5 multi-modality). Twenty-six (26) patients (65%) presented initially with hemorrhage, 11 (27.5%) with ischemic symptoms, and 3 (7.5%) were diagnosed incidentally. Complete hemorrhage control (no new or recurrent hemorrhage) was achieved in 100% of patients. Five patients underwent a second course of CKRS due to residual nidus after at least 3 years of follow up.

Conclusion: Our study presents a large cohort of SCAVMs successfully treated with CKRS with a 100% rate of new or recurrent hemorrhage prevention. CKRS is a safe and effective treatment option in patients with SCAVMs.



24-26 October 2016
Napa, California

ABSTRACTS/ORAL PRESENTATIONS

10:00 AM - 10:10 AM

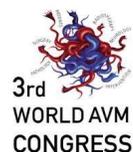
The Study on the Treatment of Brain AVMs (TOBAS): Feasibility of a Randomized Controlled Care Trial and Registry.

Elsa MAGRO, MD, PhDs¹, Jean-Christophe GENTRIC², Chiraz CHAALALA³, David ROBERGE⁴, Alain WEILL⁵, Daniel ROY⁵, Michel W. BOJANOWSKI⁶, Tim E. DARSAUT⁷, Jean RAYMOND⁵.

¹Neurosurgery, Centre Hospitalier Universitaire Brest, BREST, France, ²Interventional Neuroradiology, Centre Hospitalier Universitaire Brest, BREST, France, ³Neurosurgery, Centre Hospitalier Universitaire Montreal, Montreal, QC, Canada, ⁴Radiotherapy, Centre Hospitalier Universitaire Montreal, Montréal, QC, Canada, ⁵Interventional Neuroradiology, Centre Hospitalier Universitaire Montreal, Montréal, QC, Canada, ⁶Neurosurgery, Centre Hospitalier Universitaire Montreal, Montréal, QC, Canada, ⁷Neurosurgery, University of Alberta, Hospital Mackenzie Sciences Center, EDMONTON, AB, Canada.

Context: The management of brain arteriovenous malformations (bAVMs) remains controversial. The treatment of bAVM study (TOBAS) was designed to provide a clinical research framework to test various management options and verify results in real time. **Objective:** To study trial feasibility, recruitment rates, patient allocation to the various management groups, and estimates the frequency of crossovers, prior to expansion of the study to international centers. **Methods:** TOBAS is a randomized care trial (RCT) and registry designed to include all bAVM patients and offer randomized allocation of curative versus conservative management to patients eligible for both options. The primary outcome is death from any cause or disabling stroke resulting in mRS >2 at 10 years. TOBAS also includes a second nested randomized study on the role of adjunctive pre-embolization. Randomization is stratified according to intended primary interventional management modality (surgery, radiation therapy, or embolization). A minimization algorithm balances groups with respect to haemorrhagic presentation and Spetzler-Martin AVM grade (I-II versus III-V). Patients managed according to clinical judgment alone are entered in the registry. A pilot phase was initiated to estimate the number and characteristics of patients enrolled, to analyze the proportion of patients allocated to the various groups and the frequency of cross-overs. **Results:** From June 2014 to June 2016, 107 patients were enrolled, 46 in the RCT and 61 in the registry. There were 53 unruptured and 54 ruptured AVM patients (67 grade I-II and 40 grade III-V). Twenty-three patients were included in the first RCT (observation versus intervention) and 40 in the second (pre-embolization or not); 17 in both RCTs. Three RCT patients crossed-over from interventional to conservative management, and one cross-over from conservative to interventional. **Conclusion:** The pilot study shows promising recruitment. Whether TOBAS will provide meaningful results will depend on the recruitment of a sufficient number of participating centers (Clinical Trials.gov, ID:NCT02098252)

24-26 October 2016
Napa, California



POSTER PRESENTATIONS

1. Increase Endoglin Gene Deletion and Co-deletion of EphrinB2 Enhanced Arteriovenous Malformation in Mouse Enhanced Arteriovenous Malformation in Mouse

Rui Zhang, PhD, Wan Zhu, Li Ma, Man Luo, Lei Zhan, Hua Su, MD.

Anesthesia, University of California, San Francisco, San Francisco, CA, USA

Background and Purpose: *Endoglin (Eng)* is an AVM causative gene. In mouse, global *Eng* deletion induced by a wild-type cre (cre) resulted in AVM around the skin wound and the brain angiogenic region, but not in the intestine. We hypothesize that using a codon-improved cre (icre) to increase *Eng* gene deletion plus deletion of *EphrinB2* gene, a determinant of arterial endothelial differentiation, will cause AVM formation in the intestine and enhance AVM severity in other organs. **Methods:** *Eng* were deleted in adult *Eng* floxed mice (*Eng*^{2f/2f}) globally using a rosa promoter driving estrogen inducible cre (Rosa-creER) or in endothelial cells using a platelet derived growth factor b promoter driving estrogen inducible icre (*pdgfb-icreER*). *Pdgfb-icreER* was also used to mediate endothelial deletion of *EphrinB2*. An adeno-associated viral vector expressing vascular endothelial growth factor (AAV-VEGF) was injected into brain of mice with *Eng* or *Eng* plus *EphrinB2* gene-deletion to induce brain AVM. **Results:** Compared with Rosa-CreER mediated global *Eng* deletion, *pdgfb-icreER* induced endothelial *Eng* deletion did not increase the number of abnormal vessels (P=0.39), but reduced vascular smooth muscle coverage (P=0.03) and increased hemorrhage (P=0.04) in the brain AVM lesion. About 12.5% mice with *pdgfb-icreER*-induced endothelial *Eng* deletion developed AVM in the intestine. Additional endothelial deletion of *EphrinB2* gene increased number of abnormal vessels in the brain (P=0.09) and the prevalence of AVM in the intestine (60%). **Conclusion:** Endothelial specific deletion of *Eng* using codon-improved cre recombinase induced AVM formation in the intestine and increased the severity of AVM in the brain. EphrinB2 has an additional effect with *Eng* in AVM pathogenesis. These data indicated a positive correlation between the degree of gene mutations and AVM severity, and dysregulation of endothelial arteriovenous specification enhances AVM formation and progression.

2. Safety and Efficacy of Two BAVM Embolization Methods: with Glubran or Onyx — Results of a Consecutive Series in a Single Constitute xuying he, Ph.D.

Neurosurgery, Zhujiang Hospital of Southern Medical University, Guangzhou, China.

INTRODUCTION/PURPOSE: To compare the safety and efficacy of two BAVM embolization methods: with Glubran or Onyx.

METHODS: We reviewed the consecutive series of 465 cases of BAVMs, treated in our institute from 2011 to 2015. All the treatments were started with embolization. The embolic material was Glubran and onyx. There is no mixture of these two materials in single patient. Among those, 158 cases followed with stereotactic radiosurgery (SRS). 5 cases were obliged to have the surgical removal of AVMs because of unexpected ruptured complication during or after embolization.

RESULTS: 796 procedures of embolization were performed in 465 cases. 158 cases were followed with stereotactic radiosurgery. AVM occlusion rate of embolization is 21.08% (98/465). Total occlusion of nidus was achieved in 207 cases (44.51%). The overall complication was 4.09% (19/465), morbidity was

1.07% (5/465) and mortality was 0.21% (1/465). Glubran was used in 765 procedures in 440 cases, one procedure in 187 cases and twice or more in 253 cases. AVM occlusion rate of embolization only is 20.91% (92/440). With the combination of SRS, the total occlusion was achieved in 201/440 (45.68%). Procedure related rupture occurred in 13 cases, with permanent neurological deficits in 3 cases and 1 death. Ischemia events happened in 4 cases, with permanent neurological deficits in 2 cases. The complication with Glubran embolization was 3.86%(17/440), morbidity 1.14%, mortality 0.22%. Onyx was used in 25 cases with 31 procedures. No additional SRS was used in this group. Total occlusion was achieved in 6 cases (24%), rupture happened in 2 cases (8%) without permanent deficits. There was no ischemic complication or death.

CONCLUSIONS: Attempts to achieve higher occlusion rate with the method of embolization only could bring more complications. Glubran embolization combined with SRS could be helpful to achieve higher obliteration rate of BAVM.

3. Rationale for a Randomized Trial for Unbled Spetzler-Martin Grade 1 brain AVMs

Benjamin R. Kummer, MD¹, JP Mohr¹, Michael Parides², Christian Stapf³, Jessica Overbey², Marco Antonio Stefani⁴, Rustam Al-Shahi Salman⁵, ARUBA Clinical Trials Group.

¹Neurology, Columbia University, New York, NY, USA, ²International Center for Health Outcomes and innovation Research (InCHOIR), Department of Population, Ichan School of Medicine, New York, NY, USA, ³Neurology, University of Montreal, Montreal, QC, Canada, ⁴Institute of Health Sciences, Federal University of Rio Grande do Sul, Porto Alegre, Brazil, ⁵Neurology, Edinburgh University, Edinburgh, United Kingdom.

INTRODUCTION/PURPOSE: Proposal of a randomized clinical trial for unbled Spetzler-Martin Grade 1's

METHODS: Same randomization eligibility and management options for those randomized to intervention as for the ARUBA trial

RESULTS: The data at a mean of 48 months demonstrate no significant difference in outcomes for the medical or interventional arms for Grade 1 cases in the 'as randomized' or 'as treated' analyses.

CONCLUSIONS: The ARUBA data justify the current proposal.

4. Imaging Properties of the New Embolic Agent PHIL Compared to ONYX A Single Centre Experience in more than 50 Cases

Markus Holtmannspötter, Sr., MD, Mats E. Cronqvist, Sr.
Neuroradiology, Rigshospital, Copenhagen, Denmark.

INTRODUCTION/PURPOSE: With Onyx, attenuation under fluoro is achieved by a mixture with tantalum powder, the attenuation of PHIL is achieved by covalently bound iodine. According to the physical differences between these substances imaging properties differ respectively. In the endovascular procedure itself, a proper visibility under fluoro conditions is crucial, an unambiguous contrast behavior in follow up imaging however is important too. **METHODS:** Analysis of 50 endovascular treatments with PHIL regarding the imaging properties of PHIL and ONYX during intervention and follow up **RESULTS:** Under fluoro conditions the visibility of ONYX has been slightly better than with PHIL. In larger amounts of injected embolic agent the lower attenuation of PHIL has been advantageous, as the superimposed anatomical structures and the microcatheter weren't completely opacified as it often was the case with ONYX. 3D-angiograms following embolization with ONYX had a lot of artefacts, whereas 3D-angiograms after embolization with PHIL remained undisturbed in their quality. Evaluation of parenchymal changes

by MRI in follow up imaging provided excellent quality after usage of both PHIL or ONYX. Evaluation of the remaining nidus after partial embolization by MR-angiography was only possible after usage of ONYX, which had an unambiguous contrast towards perfused vessels. PHIL however could not always be safely differentiated from remaining nidus. In contrast CTA and rotational 3d-angiography allowed detailed analysis of remaining nidus vessels after use of PHIL but was impossible after usage of ONYX. CONCLUSIONS: PHIL in the treatment of AVMs simplifies post interventional imaging by CTA or Dyna-CT. Detailed analysis to evaluate which parts of the nidus have been embolized is possible. The quality of parenchymal imaging by MRI is excellent with both of the embolic agents. Radio surgical planning after embolization with PHIL should be based on CTA or 3D-angiograms and not on MRA, as MRA can't differentiate safely between embolized and perfused nidus.

5. Endovascular Embolization of Brain and Head and Neck Arteriovenous Malformations Using Precipitating Hydrophobic Injectable Liquid (PHIL); Preliminary Single Center Experience.

Shorog Althubait, MD., Sultan ALQAHTANI, MD., FRCPC..

Interventional Neuroradiology, King Fahad Medical City, Riyadh, Saudi Arabia.

Objective: To describe our experience in treating cerebral and head and neck arteriovenous malformations (AVMs) with the new precipitating hydrophobic injectable liquid (PHIL) embolic material.

Material and Methods: Between January 2015 and June 2016 we had treated twenty-two patients with twenty-eight sessions of embolization using PHIL. There were twelve women and ten men with a mean age of 33 years. (median 35, range 8-66 year). The cerebral AVMs were eighteen patients all presented with intracranial hemorrhage except one with severe left sided trigeminal neuralgia. Four patients were presented with extracranial head and neck AVMs. PHIL was used as sole endovascular embolic agent in twenty patients (80%) and in addition to previously incomplete treatment to onyx liquid embolic in (20%) of patients. Three cerebral AVMs underwent complete surgical resection post embolization and two cerebral AVMs completed treatment by radiosurgery.

Result: The total cerebral AVMs were eighteen patients, seventeen were ruptured cerebral AVMs (94.4%) and one unruptured (5.6%) who presented with severe trigeminal neuralgia. The head and neck AVMs were four patients only one presented with uncontrolled epistaxis. All procedures were done under general anesthesia and Apollo microcatheters were used for intranidal navigation in all cases. Complete occlusion of cerebral AVMs achieved in eleven patients (61%), Five patients complete cure achieved using adjuvants radiosurgery or surgical resection and subtotal occlusion still in two patients in whom they require further follow-up. The four extracranial head and neck AVMs group were treated with PHIL embolization with complete occlusion in all patients (100%). Procedural complications occurred in one patient (4%) who had intraventricular hemorrhage during the procedure which treated conservatively and recovered completely.

Conclusion: In our experience PHIL is a promising new liquid embolic agent which shows more extra advantages to the available products for cerebral and head and neck AVMs treatment, however further randomized control trials are required.

6. Endovascular Treatment of Brain AVMs with the SQUID

Gyula Gál, M D¹, Peter Birkeland².

¹Dept. of Radiology, Odense University Hospital, Odense, Denmark, ²Dept. of Neurosurgery, Odense University Hospital, Odense, Denmark.

Purpose: To evaluate the angiographic and clinical results following endovascular treatment of brain AVMs, with a recently developed, non-adhesive liquid embolic agent. **Materials and methods:** SQUID is a modified Ethylene-Vinyl Alcohol copolymer dissolved in DMSO and mixed with micronized Tantalum powder. The smaller size of tantalum particles is supposed to result in decreased viscosity, improved penetration and better radiographic visualization of the embolic agent when compared to Onyx. Between December 2011 and May 2016, 61 patients with 62 brain AVMs, age 6-77 years, underwent endovascular treatment at the Odense University Hospital using transarterial and in one case transvenous injections of SQUID. There were 32 males and 29 females. 22 AVMs were ruptured, the rest elective. According to the Spetzler-Martin classification, 3 AVMs were grade 1, 31 grade 2, 16 grade 3, 11 grade 4, and one grade 5. Superselective catheterization of the feeding branches were performed with Sonic detachable microcatheters, achieving intranidal position of the tip of the microcatheter. The injection of the SQUID was performed in high grade fluoroscopy in 9 cases, the endovascular therapy was combined with surgery, of which 3 were elective, the rest surgical evacuation of the hematoma directly after the embolization, while in two cases with radiation therapy. **Results:** Total occlusion with embolization alone was achieved in 32 patients, confirmed by follow-up angiographies. Additionally 7 AVMs were eliminated with the combination embolization & surgery, and two with embolization & radiation. In 7 cases, subtotal occlusion was achieved. 4 patients were lost for follow up, due to death, the rest is ongoing. 7 patients bled within one month following the treatment, one of them died.

Conclusion: Endovascular treatment of brain AVMS with SQUID is feasible and safe. In the authors' experience, SQUID offers promising advantages when compared to Onyx.

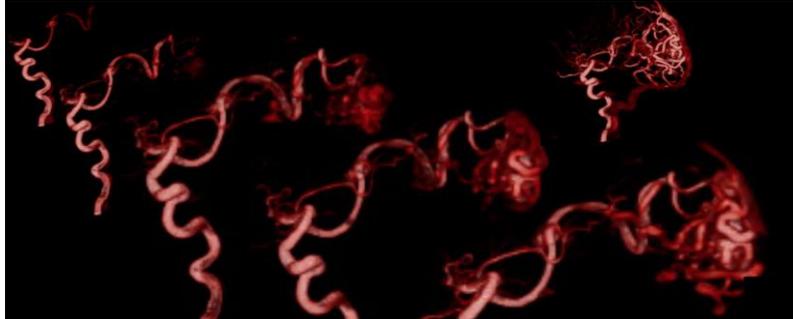
7. New Rotational Angiography Technique Resolved In Time (Four Dimensional Digital Subtraction Angiography 4D DSA) For The Study Of Intracranial Arteriovenous Malformations Angioarchitecture : Description Of The Technique, And Agreement Comparison With 2D DSA And 4D

Magnetic Resonance Angiography (MRA) Julien Ognard, M.D., M.Sc.¹, Elsa Magro, M.D., M.Sc.², Michel Nonent³, Romuald Seizeur², Jean Raymond⁴, Jean-Christophe Gentric¹.

¹Interventional Neuroradiology, Brest University Hospital, Brest, France, ²Neurosurgery, Brest University Hospital, Brest, France, ³Interventional Imaging, Brest University Hospital, Brest, France, ⁴Interventional Neuroradiology, CHRC - Montreal University, Montreal, QC, Canada.

PURPOSE The aim of this study was to assess the applicability of four-dimensional(4D) Digital Subtracted Angiography(DSA) to provide angioarchitectural details of intracranial arteriovenous malformations(AVM). Through a comparison with 2DDSA and 4DMR angiography(MRA). **METHODS** We included 12patients with clinical indications of evaluation of arteriovenous malformations. Standardized 2D DSA evaluations were done for each patient, as well as a 4DDSA acquisition (Siemens Artis Q) and 4DMRA(Philips Achieva 3TX). All clinically relevant angio-architectural features, including Spetzler-Martin grade, were assessed by three blinded reviewers in a standardized comparison with 2DDSA and 4DMRA reconstructions on a single workstation. A second analyse was later also performed by one reviewer. **RESULTS** The results for all the angio-architectural features are described by (Interobserver kappa ; intraobserver kappa, respectively for 4DDSA/4DMRA/2DDSA) : presence of a shunt (1;1/0,91;0,87/0,92;), number of prenidial aneurysm (0,70;0,74/0,28;1/0,86;1), number of nidial aneurysm (0,15;1/0,12;1/0,57;0,56), number of venous aneurysm (0,51;0,81/0,36;0,78/0,71;0,79),

number of arterial stenosis (0,50;0,51/0,26;0,41/0,62 ;1), number of venous stenosis (0,19;0,11/0,15;0,10/0,21;0,39), number of afferences (0,10;0,13/0,11;0,13/0,21;0,52), number of efference (0,30;0,34/0,21;0,28/0,43;1), nidus localisation (0,74;1/0,80;1/1;1), classification of Spetzler-Martin (0,31;0,38/0,32;0,47/0,43;0,33). **CONCLUSIONS** 4DDSA displays well the angioarchitecture of the AVM and our agreement study shows the same results in comparison of the invasive and non invasive gold standard 2DDSA or 4DMRA assessing angioarchitectural features of the brain AVMs.



8. Preliminary Experience and Short Term Follow-Up Results in Endovascular Treatment of Cranial Arteriovenous Malformations Using PHIL (Precipitating Hydrophobic Injectable Liquid) Embolic Agent

Han Seng Chew, MBChB, Saleh Lamin.

Neuroradiology, Queen Elizabeth Hospital Birmingham, U.K., Birmingham, United Kingdom.

INTRODUCTION/PURPOSE:

We aim to retrospectively assess the efficacy and safety of PHIL (Precipitating Hydrophobic Injectable Liquid, Microvention, Inc. California, USA), a new DMSO based liquid embolic agent, in the treatment of patients with cranial arteriovenous malformations (AVM). PHIL is CE marked and currently available for clinical use in Europe.

METHODS:

22 consecutive AVM patients treated by endovascular embolization with PHIL between September 2014 and July 2016 were enrolled in our study. The primary endpoint was the rate of complete AVM occlusion immediately post procedure and at 6-month follow up. Secondary endpoints included rate of adverse event and clinical status of the patient.

RESULTS:

The AVM grades are as follow: 2 patients with Spetzler-Martin Grade 1, 3 patients with Grade 2, 10 patients with Grade 3, 5 patients with Grade 4 and 2 patients with Grade 5. Majority of the patients presented with history of AVM rupture.

Total nidus occlusion was achieved in 7/22 patients (32%) immediately post procedure - 6/7 AVMs remained completely occluded at 6-month follow up. 4/22 (18%) had near complete occlusion and 11/22 partial occlusion (50%). Three patients experienced adverse events, including one case of asymptomatic on-table rupture, one case of catheter retention with AICA occlusion leading to unilateral deafness and one case of inadvertent reflux into the PCA. No mortality was encountered.

CONCLUSIONS:

In our experience, PHIL is effective and safe for the management of patients with cranial AVMs, showing similar clinical results to Onyx liquid embolic system, with the added advantage of easier material preparation and significant reduction in radiographic artefacts especially on CT.

9. Use of Adenosine-Induced Cardiac Standstill for Trans-Arterial Embolization of Vein of Galen Malformations in the Pediatric Population

Nam K. Yoon, MD, Philipp Tausky.

University of Utah, Salt Lake City, UT, USA.

INTRODUCTION/PURPOSE: Vein of Galen malformations are high-flow arteriovenous malformations that are typically diagnosed during infancy and can present with heart failure, hydrocephalus, developmental delay and intracranial hemorrhage. As open surgical treatment is associated with high morbidity and mortality, treatment is increasingly done through endovascular embolization. However, embolization of these arteriovenous malformations can be difficult because of the high flow nature of these lesions. The use of adenosine-induced cardiac standstill to allow safe embolization of these lesions has been described previously in adults, but not in the pediatric population.

METHODS: We present three cases in two pediatric patients who underwent trans-arterial Onyx embolization of their Vein of Galen malformations using adenosine to induce temporary cardiac standstill. One patient underwent two separate procedures for progressive hydrocephalus presumably from venous congestion causing impaired drainage of cerebrospinal fluid. The second patient underwent more urgent embolization for right heart failure as an infant.

RESULTS: Following the procedure, the head circumference of the first patient normalized on growth curves. The second patient's right heart pressures normalized and he did not develop any other symptoms. Both patients had good neurologic outcomes at last follow-up.

CONCLUSIONS: Based on our experience of three cases in two pediatric patients, we submit that the use of adenosine to induce cardiac standstill is well tolerated and allows safe trans-arterial embolization of high flow Vein of Galen malformations in the pediatric population.

10. A Proposed Grading System to Evaluate the Endovascular Curability of Deep-Seated Arteriovenous Malformations:

Thomas Robert, MD, Raphael Blanc, Gabriele Ciccio, Stanislas Smajda, Daniele Botta, Hocine Redjem, Robert Fahed, Michel Piotin.

Interventional Neuroradiology, Rothschild Fondation Hospital, Paris, France.

A Proposed Grading System to Evaluate the Endovascular Curability of Deep-Seated Arteriovenous Malformations

Th.Robert M.D, R.Blanc M.D, M.Sc, G.Ciccio M.D, S.Smajda M.D, D.Botta M.D, H.Redjem M.D, R.Fahed M.D, M.Piotin M.D, Ph.D.

Department of Interventional Neuroradiology, Rothschild Foundation Hospital, Paris, France.

BACKGROUND: The high tendency to bleed of deep-seated AVMs is the first argument to propose an aggressive treatment. In the literature discussing about endovascular therapy, AVMs of the basal ganglia, the semi-ovale center and brainstem are always considered as a unique entity.

METHODS: From 1995 to 2013, clinical and angiographic data of cerebral AVMs were prospectively collected. We reviewed data from patients treated for a deep-seated AVM with the goal to distinguish factors that influencing the curability and the outcome of these AVMs.

RESULTS: 134 patients (mean age: 28 years) were consecutively treated by endovascular techniques. We described an anatomical classification regarding the exact location of the nidus and distinguish 5 different sub-types (anterior, lateral, medial, posterior and brainstem). Then, we described a grading system based on statistical analysis of our series to evaluate the curability of a deep AVM. This comprehensive score depended of the Spetzler-Martin grade, the location of the nidus, its type, arterial

feeders and venous drainage.

CONCLUSIONS: Deep-seated AVMs could be classified regarding their exact location; we could distinguish 5 different sub-types (anterior, lateral, medial, posterior and brainstem). Each group presented different arterial supply and venous drainage that influence treatment possibilities. The comprehensive grading system that we proposed in this study has to be tested in another deep-seated AVMs population.

11. Balloon Plugging Technique for Intranidal Embolization of AVMs Technique for Intra-Nidal Treatment of AVMs Technique for Intra-Nidal Treatment of AVMs

Mohamed Aggour, MD.

INR Unit, University Hospitals of Saint Etienne, saint Etienne, France.

Introduction and Purpose: Many techniques were described to treat AVMs with various liquid embolic agents. Difficulties are commonly encountered which includes difficult navigation, distal migration, aspiration of contrast media due to the intr-nidal high flow, reflux of liquid embolic agents, perforation and catheter rupture. Long procedure times are also encountered in most of the cases. It is important to look for new techniques in order to minimize those various common difficulties. Materials and Methods The balloon plugging technique (use of a double lumen balloon catheter) was evaluated prospectively in our institution. Different liquid embolic agents were used to treat 18 AVMs via 30 different afferents intra-nidally. Feasibility, procedure time, navigation time, evaluation of nidal architecture, distal migration and reflux of liquid embolic agents were observed. Results Navigation was feasible in all selected cases. Procedure and navigation time were very short and will be presented in details. Better evaluation of nidal architecture was obtained when balloon is inflated. No distal migration or reflux was observed in all studied cases. We had one perforation while doing a supra-selective intra-nidal contrast injection with minimal asymptomatic hemorrhage. Conclusion Balloon plugging technique overcomes most of the difficulties associated with AVMs embolization. Special balloons dedicated for AVMs embolization are a very useful tool to be developed and introduced in the very near future.

12. DSA Dynavision in Endovascular Treatment Planning for Intracranial Dural AVF

Alexander Botsford, MD, Jai JS Shankar.

Diagnostic Radiology, Dalhousie University, Halifax, NS, Canada.

INTRODUCTION/PURPOSE: Intracranial dural arteriovenous fistulas (DAVFs) are rare complex vascular malformations with serious natural history in the presence of cortical venous reflux (CVR). Patients with failed or partial endovascular treatments of these lesions undergo complex vascular surgery. Combination of CT or MR angiography and DSA are used in the pre-treatment evaluation of intracranial DAVFs. We found DSA Dynavision with multi-planar reconstruction very helpful in understanding the complex anatomy and planning both approach and method of treatment. We believe this better understanding of the anatomy results in better cure rate of DAVF using endovascular embolization. The purpose of our study was to examine whether using DSA Dynavision in pre-treatment planning would lead to an improved reduction in CVR post-procedure, greater rates of complete occlusion, and reduction in need for post-embolization surgery. **METHODS:** Patients with DAVF from 1998 to July 2015, were retrospectively identified from our interventional neuroradiology database. Patients were assessed and were divided into those with DSA Dynavision and those without. They were compared for procedural time, angiographic evidence of cure, rates of resolution of CVR, complications, and need for

post-embolization surgery. **RESULTS:** 86% of 28 patients (mean age 57 years, range 1.67-84 years) had Borden type 3 DAVF and 93% had CVR. DSA Dynavision was used in 14/28 (50%) of patients. Fewer patients with DSA Dynavision required post- endovascular embolization surgery (7% vs. 50%, $p=0.01$) and had CVR post-procedure (71% vs. 29%, $p=0.023$). Mean procedural time (207 vs. 249 minutes; $p=0.40$); complication rates (29% vs. 29%, $p=1.0$); rate of immediate angiographic occlusion (64% vs. 29%, $p=0.061$) and reported resolution of symptoms (79% vs. 53%, $p=0.18$) were not significantly different. Mean clinical follow-up time was 35 weeks. **CONCLUSIONS:** The use of DSA Dynavision in planning of endovascular treatment of DAVF results in higher rates of elimination of CVR and less need for post-embolization surgery.

13. Management of Arteriovenous Malformations (AVMs) Associated with Developmental Venous Anomalies (DVAs)

Michael Zhang, MD¹, Mario K. Teo¹, Robert Dodd¹, Michael Marks², Gary K. Steinberg¹.

¹Neurosurgery, Stanford School of Medicine, Stanford, CA, USA, ²Radiology, Stanford School of Medicine, Stanford, CA, USA.

Introduction: The classification of cerebrovascular malformations has yielded intermediary lesions that warrant ongoing review to clarify their optimal treatment. We present 2 cases of AVMs associated with DVA, discuss management strategies, and review the published literature on this unique entity.

Methods: AVM cases associated with DVA were identified from a locally held database. A focused literature search was also conducted spanning 1980 to 2016.

Results: Case 1: A 29-year-old female presenting with parenchymal hemorrhage, with left homonymous hemianopia, was found to have an MCA- and PCA-fed, complex right parietal SM4 AVM, and major venous drainage via a DVA with multiple adjacent “caput medusa” small vessels to the superior sagittal sinus (SSS), along with a smaller component with deep venous drainage. Case 2: A 34-year-old female evaluated for night tremors and incontinence underwent imaging that revealed a left parietal SM1 AVM with venous drainage to the SSS via a DVA. Including our cases, 20 co-existing AVM and DVA have been described in the literature. Patient mean age was 31 (range 6-67), with no gender preference (50% male). At presentation, 70% had radiographic evidence of hemorrhage. Staged obliteration of the lesions were performed, which included multimodality treatment in 4 cases, stereotactic radiosurgery in 8 cases, and serial embolization in 9 cases. Surgical resection was performed in 6 cases. The radiographic follow-up of these rare entities focused on AVM resolution, which was largely successful.

Conclusion: Patients with co-existing AVM and DVA tend to have hemorrhagic presentation, which is likely associated with the delicate hemodynamic balance between malformations. Resolution of symptoms can be achieved without complete resection, and frequently managed by less invasive considerations. Contrary to traditional AVM management, it is critical that the draining vein via the DVA is left to preserve the venous drainage of its associated brain parenchyma.

14. Management of Multiple Cerebral Arteriovenous Malformations in a Non-Pediatric Population

Thomas Robert, MD, Raphael Blanc, Gabriele Ciccio, Stanislas Smajda, Daniele Botta, Hocine Redjem, Robert Fahed, Michel Piotin.

Interventional Neuroradiology, Rothschild Fondation Hospital, Paris, France.

Objectives: The occurrence of concomittant multiple cerebral arteriovenous malformations (mAVMs) is often associated with the hereditary hemorrhagic telangiectasia (HHT) or a craniofacial arteriovenous

metameric syndrome (CAMS) and frequently occurred in the pediatric population.

Patients and Methods : Between 1995 and 2013, demographic, clinical and angiographic data of cerebral AVMs have been prospectively collected. We retrospectively analysed data of patients presenting multiple cerebral AVMs.

Results : Six patients (mean age : 44 years, male to female ratio : 5) presented an angiographic diagnosis of cerebral mAVMs. Only one of them was known to have a HHT. Five patients presented two cerebral AVMs and one patient had 3. Three AVMs (23.1%) presented a bleeding at admission. Three patients had supratentorial mAVMs only and the three others had supra and infratentorial AVMs. Only one patient suffered from a bleeding of more than one of his mAVMs with an interval of 23 years.

Conclusion : For asymptomatic AVMs discovered incidentally without angiographic bleeding risk, we propose a therapeutic abstention. In case of AVM rupture and bleeding, the other « associated » AVMs (discovered through a complete angiographic assessment) should also be treated if they are not located in an eloquent area and if the treatment does not present technical difficulties. AVMs with a history of bleeding, or associated to angiographic risks have to be treated more aggressively.

15. Follow-up Time Needed for Non-inferiority of Intervention in the ARUBA Trial.

Aditya Iyer, MD, MS, Eric Sussman, Gary Steinberg.
Stanford University, Stanford, CA, USA.

OBJECTIVE: To understand the follow-up needed for a clinical trial such as the ARUBA trial to truly demonstrate the non-inferiority of intervention for AVMs using simple mathematical concepts.

METHODS: The number of years until an AVM ruptures is a geometric random variable N with parameter p where $p+q=1$. The expected number of years follows a geometric series, namely: $N=30.7\%$ of patients in the ARUBA trial reached the primary endpoint of stroke or death. The ARUBA trial estimates a 2.2% annual hemorrhage rate from untreated AVMs.

RESULTS: Using the geometric distribution function and the percentages provided by the ARUBA trial, $p=0.022$. Solving for N , $N=16.5$ years.

CONCLUSIONS: A minimum of 16.5 years follow-up would be required to potentially demonstrate non-inferiority for the intervention group for AVMs. This mathematical illustration demonstrates the need to reevaluate how clinical trials are stopped early in favor of one arm.

16. Interventional Therapy for Brain AVMs Before and After ARUBA

Eric S. Sussman, MD, Aditya K. Iyer, Mario Teo, Gary K. Steinberg.
Neurosurgery, Stanford University, Palo Alto, CA, USA.

Introduction: The ARUBA Trial (2014) concluded that medical management alone is superior to medical management plus interventional therapy in the management of unruptured brain arteriovenous malformations (bAVMs). This sparked considerable controversy among involved healthcare providers.

Methods: This was a retrospective review of a prospectively maintained database of bAVMs treated at Stanford from January 2012 through July 2015. The study period was divided into three phases: the 'pre-ARUBA phase', consisting of the 17 months prior to the presentation of ARUBA Trial Results at the XXII European Stroke Conference (ESC) (Jan2012 – May2013), the 'transition phase', consisting of the 8 months between ESC and the ARUBA publication (June2013 – Feb2014), and the 'post-ARUBA phase', or the 17 months following publication (Feb2014 – July2015).

Results: Thirty patients were treated in the 'pre-ARUBA phase' (1.8/month), 23 in the 'transition phase'

(2.7/month) and 37 in the 'post-ARUBA phase' (2.2/month). The percentage of bAVMs that were unruptured at the time of presentation was 40%, 57%, and 46%, respectively (chi-square statistic=5.96, p=0.05), and the mean S-M for each phase was 2.6, 3.0 and 2.4, respectively. The percentage of patients undergoing surgery was 60% in both the pre- and post-ARUBA phases, whereas the percentage undergoing CyberKnife radiosurgery was 23% and 22%, respectively. There is no difference in the percentage of patients treated with each modality in the pre- and post-ARUBA phases (chi-square statistic=0.41, p=0.94).

Conclusions: The volume and type (ruptured vs. unruptured, S-M Grade) of bAVMs treated at one large tertiary center has been relatively unchanged in the period of time leading up to and following ARUBA. Furthermore, there has been no change in the frequency of the various treatment modalities throughout the study. Additional research is necessary to more thoroughly characterize the impact of ARUBA on the treatment patterns of bAVMS.

17. Transitional Developmental Venous Anomalies: Clinical, Angiographic, and Arterial Spin Labeling MRI Features.

Nicholas Telischak, MD, MS¹, Jeremy Heit², Gary Steinberg³, Michael Iv⁴.

¹Interventional Neuroradiology, California Pacific Medical Center, San Francisco, CA, USA, ²Interventional Neuroradiology, Stanford University Medical Center, Stanford, CA, USA, ³Neurosurgery, Stanford University Medical Center, Stanford, CA, USA, ⁴Neuroradiology, Stanford University Medical Center, Stanford, CA, USA.

INTRODUCTION: Transitional developmental venous anomalies (tDVAs) are poorly understood cerebrovascular malformations that have imaging characteristics of both DVAs and arteriovenous malformations (AVMs). While tDVAs have the appearance of a DVA (without a parenchymal nidus of an AVM), they exhibit early arteriovenous shunting. The natural history of tDVAs is unknown. Arterial spin labeling (ASL) is a sensitive magnetic resonance imaging (MRI) technique for detection of vascular shunting lesions and has led to more transitional lesions being discovered.

METHODS: We performed an IRB-approved, retrospective chart-review of patients with DVA-like lesions that had abnormal ASL signal from April 2006 to April 2016. We hypothesize that these may represent transitional DVAs. Clinical presentation, imaging findings, treatment and clinical outcome were recorded.

RESULTS: Thirty-three patients (15 female, 18 male; mean 52 years) had MRI findings of a DVA-like lesion with ASL signal seen in the DVA itself (n=27) or within the vein or sinus (n=6). Six patients had an angiogram (DSA). Two neuroradiologists evaluated the MRI for presence and location of ASL signal and the available DSA for the presence and location of early arteriovenous shunting. Of the DSAs available, two were positive for arteriovenous shunting and these patients had ASL signal in a vein or sinus. Therefore, we feel that this pattern of ASL associated with DVA-like lesions is predictive of tDVAs. Of those patients, one lesion underwent partial surgical resection followed by radiosurgery because of the lesion's high degree of arteriovenous shunting. None developed symptoms attributable to their lesion.

CONCLUSIONS: The history of tDVAs is unknown but risk is likely lower than AVMs. When a DVA-like lesion is encountered with ASL signal in a vein or sinus, a DSA can be performed for confirmation and/or consideration of treatment. Continued observation with MRI is a non-invasive alternative in asymptomatic patients, since tDVAs appear to behave differently than AVMs.

18. EMBRYOLOGICAL CONSIDERATIONS IN BRAIN AVM

Maria A. de Miquel, MD PhD¹, Rosa Mirapeix², Sonia Aixut¹, Alex Luttich¹, Lucia Aja¹, Roger Barranco¹.

¹Vascular Neuroradiology, Hospital Universitari de Bellvitge, L'Hospitalet de Llobregat, Spain,

²Departamento de Ciencias Morfológicas, Universidad Autónoma de Barcelona, Bellaterra (Barcelona), Spain.

Introduction: The old approach for understanding vessel development was centred in observations about the progressive vascular distribution during the different stages of the embryo. Nowadays, interest is more focused in cellular and extracellular-environmental mechanisms affecting cell differentiation, and distribution. Reviewing those concepts of the beginning of last century, combining them with modern observations and using, at the same time, our embryological preparations of different stages until the early fetal period, we aim to get a better understanding about the processes involved in arterial and mainly venous distribution. The final goal of this work is to apply those combined observations to get some light about the genesis of Brain Arteriovenous Malformations (BAVM).

Material and Methods: 35 embryos and fetuses between 8 mm and 120 mm Crown-Rump length have been reviewed in this study. Venous and arterial anatomy has been determined by following the vessels with the aid of the microscope. This information has been evaluated in combination with angiographic and imaging data of supra- and infra-tentorial AVM found in our everyday clinical practice.

Results and Conclusions: Review of embryology shows that, mainly for veins, a process of heavy plexual expansion initiates before having the venous tree set, but along with the processes of growth is also possible to follow the later destruction of part of these plexual vessels, keeping only the main definite veins patent. Besides the proposed origins like wrong molecular environment (related, for example, to VEGF), and dural venous impairment as in Vein of Galen AVM, it could be hypothesized that occlusion of wrong pial and or dural connections could set the basis for higher venous pressure in an alternative venous structure. Maintenance of this conditions, probably besides other factors as angiogenic molecules could be related to the development of an AVM.

19. How to Deal with Postradiosurgical Minimal Residual AVMs

Maria A. de Miquel, MD, PhD, Lucia Aja, Sonia Aixut, Alex Lüttich, Roger Barranco.

Vascular Neuroradiology, Hospital Universitari de Bellvitge, L'Hospitalet de Llobregat, Spain.

INTRODUCTION/PURPOSE: Radiosurgery for brain Arteriovenous Malformations (AVM) offers angiographic cure in around 80% of AVMs smaller than 10 cc. There is a small population of patients presenting a residual nidus more than three years after the radiosurgery treatment. WFNS guidelines (1) state that repeated radiosurgery is the preferred option for most of these patients. Permanent neurological sequelae are expected to be slightly higher due to radionecrotic changes.

METHODS, RESULTS: We present five patients whose control angiograms show a minimal residual AVM more than five years after a radiosurgical treatment. There were two distinct patterns: a faint opacification of an undefined nidus with or without venous drainage (3 cases), or just one precocious vein (2 cases). In both patterns, the feeding artery was not identified. Those five patients have not been retreated, and no hemorrhagic complications have been detected. The mean interval after radiosurgery is 8,8 years (ranging from 6 to 11 years).

CONCLUSIONS: Presenting five patients harboring very small residual AVMs after radiosurgery, we would like to discuss the indication of a second radiosurgical treatment for these particular cases, and comment on the eventual benefit of a total cure at the price of a higher risk for radionecrosis.

20. Prior Embolization does not Affect AVM Obliteration or Hemorrhage following CyberKnife Radiosurgery

Aditya Iyer, MD, MS, Eric Sussman, Steven Chang.
Stanford University, Stanford, CA, USA.

OBJECTIVE: The goal was to define the long-term benefits and risks of stereotactic radiosurgery (SRS) for patients with arteriovenous malformations (AVMs) who underwent prior embolization.

METHODS: Between 1999 and 2013, the authors performed CyberKnife radiosurgery on 111 patients with brain AVMs; 57 patients had embolization of their AVMs prior to CyberKnife. Among those who underwent prior embolization, 22 (42%) had at least one prior hemorrhage and 12 (21%) had undergone prior surgical resection. The median Spetzler-Martin grade was 3, with a median target volume of 4cm³ treated with a median target dose of 20Gy.

RESULTS: Among the 57 patients who underwent CyberKnife radiosurgery following embolization, 43 (75%) had clinical and radiographic follow-up. The median follow-up time was 35 months. Only two patients had a post-radiosurgery hemorrhages, at 11 and 17 months following treatment. At the time of last follow-up, sixteen patients (37%) had stable AVMs, 22 (51%) had partial obliteration and 5 (12%) had complete obliteration. In the univariate and multivariate analyses, prior embolization was not associated with the obliteration rate ($p=0.9$, 0.7 respectively), as well as the risk of post-radiosurgery hemorrhage ($p=0.1$, 0.5 respectively).

CONCLUSIONS: In our experience, both the rates of obliteration as well as the risks of hemorrhage during the latency period were not affected by prior embolization. The role of embolization both before after CyberKnife radiosurgery for AVMs should be further explored.

21. 2D Angiotomography as an Aid to Surgical Approach Planning for Spinal Vascular Malformations

Jignesh Tailor, PhD MRCS, Daniel C. Walsh.

Department of Neurosurgery, King's College Hospital, London, United Kingdom.

Surgical extirpation is an effective treatment for spinal vascular malformations (SVM). SVM based about the anterior arterial axis and/or those with diffuse nidal elements may be well demonstrated on digital subtraction angiography (DSA) but are poorly demonstrated by conventional cross-sectional imaging (MR/CT angiography). Anterior or ventro-lateral approaches may be ideal to provide access to arterial feeding vessels or venous aneurysm. Relating the vascular anatomy to both the bony spine/skull base anatomy and the neural tissue facilitates planning of the approach. Five cases of SVM with complex vascular and/or skeletal anatomy underwent 2D-angiotomography while undergoing 3D rotational DSA. The cases included two ruptured high flow cervical dural arterio-venous fistulae (AVF), a case of fistulous arteriovenous malformation (AVM) of the conus, a ventral spinous fistulous AVM at C2 with an associated aneurysm, and a Merland type B peri-medullary fistula. The high isotropic spatial resolution allowed superior demonstration of perimedullary, extramedullary and pial nidal representations compared to conventional cross-sectional imaging as well as resolving arterial from venous phases of circulation. The information so derived was applied to surgical planning and successful surgical extirpation carried out.

22. Intraoperative DSA Image-guided Resection of Complex Intramedullary Spinal Arteriovenous Malformation: a Prospective Evaluation of efficacy

Tao Hong, M.D., Hongqi Zhang, Feng Ling, Xiaoyu Li, Yongjie Ma.

Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, China.

INTRODUCTION/PURPOSE: Intramedullary spinal arteriovenous malformations(AVMs) with an anterior spinal arterial(ASA) contribution are considered difficult to resect or embolize, given their limited surgical exposure and postoperative neurological function impairment. We first introduce the technique of intraoperative digital subtraction angiography(DSA) combined with intra-arterial methylene blue injection angiography to facilitate the complete resection of complex intramedullary spinal AVMs.

METHODS: We prospectively recruited consecutive cases of intramedullary spinal AVMs with ASA supply from Jan. 2013 to Dec. 2015. Intraoperative segmental artery DSA with the intra-arterial methylene blue injection angiography was performed in all patients. All operative reports, radiographic studies and clinical data were reviewed. Resection completeness was evaluated with 3 months DSA follow up after surgery. Long-term spinal function was defined as the Aminoff-logue score at 12 months after surgery.

RESULTS: There were 72 cases involved in this study, including 54 (75%) nidus type and 18 (25%) fistula type AVMs. Mean operation time was 435 min. This intraoperative DSA was most helpful to localize the AVM nidus precisely, recognize the remnant after the resection and distinguish the normal vessel with abnormal nidus vessel. Intraoperative methylene blue angiography via the angiographic catheter was useful to quickly recognize the nidus remnant in the operative field. 49 cases (68.1%) achieved angiographically confirmed complete resection of the nidus after operation. The long-term spinal function was stable or improved in 61 cases (84.7%). No angiographic complication was noted.

CONCLUSIONS: Intraoperative DSA combined with methylene blue angiography is an effective technique to achieve the aim of complete resection of intramedullary spinal AVMs with neurological function preservation.

23. Long-term Clinical Outcome of Intramural Spinal Cord Arteriovenous Malformation: A Study of 516 Consecutive Cases

Jia-xing Yu, M.D., Hong-qi Zhang.

Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, China, Beijing, China.

Background: The appropriate treatment of the intradural spinal cord arteriovenous malformations (SAVMs) is complicated. To obliterate a lesion completely could eliminate the pathophysiological process of the disease but it would increase the probability of iatrogenic injury of spinal cord. Whereas, a partial obliteration could minimize the iatrogenic injury but the residual malformation may lead a poor clinical outcome.

Objective: In this article, we aim to describe our treatment experiences with the intradural SAVMs depending on the long-term clinical outcomes.

Methods: 516 consecutive cases of intradural SAVMs coming from "SPINALAVM STUDY GROU" database(www.spinalavm.com)from Jan. 2007 to May. 2016 were retrospectively analysed. All of the vascular malformations that located at spinal cord medullary or perimedullary space were included. Treatments were performed with microsurgery, endovascular embolization, combined embolization-microsurgery and conservative treatment. Part of our patients accepted treatment more than once. Clinical characteristic, medical image, treatment results and follow-up information have been analysed.

Results:

The analysis is going on, and we will finish our work before October 2016. The following information will

be assessed:

1. The evolution process of the intradural SAVMs before invasive treatments.
2. The evolution process of the residual intradural SAVMs.
3. The iatrogenic injury caused by treatment itself.
4. The long-term clinical outcomes of patients whose lesion had been completely obliterated and patients whose had been partially obliterated.

Conclusions:

1. To describe the nature history of intradural SAVMs.
 2. To discuss the indications of the complete obliteration and the partial obliteration of intradural SAVMs.
-

24. Microsurgical Treatment of Intrinsic Spinal Vascular Malformations in a UK Neurovascular Centre

Menaka Paranathala, BMBCh MA MRCS, Daniel C. Walsh, FRCS(Neurosurg.).

Neurosurgery, King's College Hospital, London, United Kingdom.

Introduction/Purpose: Arteriovenous malformations derived from intrinsic blood supply of the spinal cord(SAVMs) are rare entities with uncertain natural histories. Classification systems continue to evolve. Broadly they are according to either their angio-architectural characteristics, anatomical or aetiological factors, mostly informed by small clinical case series.

Methods: We retrospectively reviewed prospectively collected data on nidal and fistulous SAVMs presenting for microsurgical treatment over an eight-year period. Neurological function was reported using the modified McCormick Grade (MMG)

Results: 15 patients are presented, comprising 5 nidal and ten fistulous SAVMs. These were distributed as follows- 6 cervical, 3 thoracic, 4 conus medullaris and 3 filum terminale. All were symptomatic at presentation. 1/5 nidal SAVMs and 3/10 fistulous SAVMs first presented to our department after haemorrhage. Duration of symptoms ranged from 2 days to 10 years. Median duration of follow-up was 30 months (Mean 32.57 months, 95% CI 16.9-48.25). 2 patients did not attend review. 5/15 SVMs had a nidal architecture although two of these had diffuse elements. 11 patients were treated surgically, 1 underwent stereotactic radiosurgery and 1 expectantly managed. Another patient declined surgery and died following haemorrhage while under follow-up. Median MMG at last follow-up for both groups was 3 (Nidal median follow-up 44 months, fistulous 18 months) Haemorrhagic presentation was an unfavourable predictor of neurological recovery for patients with glomus lesions but not necessarily for those with a fistulous architecture. In-situ disconnection was used successfully to treat two fistulous lesions. One patient exhibited a permanent post-operative 1-point reduction in MMG compared to baseline.

Conclusion: Microsurgical extirpation or in-situ disconnection was feasible in all but one case. Post-operative neurological disability appears a function of pre-operative functional ability consistent with other series. Standardised reporting of series would aid understanding of the natural history as well as therapeutic outcomes for this disease.

25. Spinal Arteriovenous Shunts below the Conus: Clinical Presentation, Radiological Findings and differential diagnosis

Tao Hong, M.D.¹, Hongqi Zhang¹, Ji Eun Park², Timo Krings³.

¹Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing, China, ²Radiology, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea, Republic of, ³Medical Imaging, Toronto Western Hospital, University of Toronto, Toronto, ON, Canada.

INTRODUCTION/PURPOSE: Spinal arteriovenous shunts below the conus constitute a peculiar group of lesions among all spinal vascular malformations, which have previously mainly been described in case reports given their rarity. The purpose of this study is to describe the classification, epidemiological features, clinical and radiological presentations, treatment and outcomes of these lesions in a consecutive series of 48 cases.

METHODS: The prospectively collected databases of two referral centers for spinal vascular lesions was retrospectively reviewed. Spinal arteriovenous shunts below the conus were defined as all dural and intradural shunts below the conus medullaris. Clinical features, radiological findings, treatment results, and clinical outcomes were assessed.

RESULTS: There were 36 men (75%) and 12 (25%) women with a mean age of 52.4 years (range, 5-81 years). Mean clinical follow-up duration was 25.7 months (range, 3-77 months). Three types of shunts were identified: filum terminale arteriovenous fistulas in 11 patients (22.9%), radicular arteriovenous shunts in 7 patients (14.6%) and spinal dural arteriovenous fistulas in 30 patients (62.5%). Radicular arteriovenous shunts presented at a younger age ($P=0.017$) and with higher incidence of back pain symptoms ($p=0.037$). A tethered spinal cord was found in 6 (54.5%) FTAVF patients, 7 (23.3%) SDAVF patients and in none of the rAVS patients ($p=0.032$). Ten patients had sacral lipomas on MRI, among which FTAVF patients showed higher incidence of sacral lipoma (5 in 11, 45.5%) compared with SDAVF (5 in 30, 16.7%) and rAVS (0%) patients. After treatment, angiographic complete obliteration rate was 89.4% and spinal function was improved significantly ($p<0.001$).

CONCLUSIONS: Based on the feeding artery and lesion location of angiography, three subtypes of spinal arteriovenous shunts below the conus can be differentiated. The shunts in this location are frequently associated with dysraphic malformations, which may suggest a particular embryological origin.

26. Selecting Less-effective Therapy, Exploring Why Obliteration Rates of BAVM fail to meet Expectations

Iacopo Chiavacci, MD, Gavin Fatania, Catia Gradil, Michael C. Bentley Morgan, Benjamin J. Varghese, Daniel Walsh.

King's College Hospital, London, United Kingdom.

OBJECTIVE: Attempts to gather high quality evidence directing treatment selection and management of Brain AVMs (BAVM) have produced controversial results. While generally agreed that obliteration of the AVM is necessary for best clinical outcomes, curative treatment is not accomplished in a significant number of patients treated in these studies. **METHODS:** The records of all consecutive patients with BAVM presenting to our multidisciplinary clinic between January 2010 and December 2014 were analysed. For patients receiving treatment, Lawton-Young supplemental scores (LY) and Pollock-Flickinger (RBAS) scores were calculated, projecting an obliteration and complication estimate for microsurgical and radiosurgical treatment. **RESULTS:** 164 patients (M 51%, F 49%) were seen (median age of 41.8 years, range 5-87 years). Patients receiving a conservative recommendation (CR) were not significantly older than those receiving an Interventional Treatment Recommendation (IR) (median age

CR 46.3 vs. IR 40.8 years, $p=0.8$, Pearson). 101 patients received treatment, with 25 receiving microsurgical treatment (MS) and 76 receiving radiosurgical treatment. Embolisation with curative intent was undertaken in 12 patients so they were excluded from this analysis. The median projected surgical obliteration rate was 90.9% (range 45.5% - 100%) for the patients receiving MS and 78.9% (range 45.5% - 100%) for those receiving radiosurgery. The RBAS projected obliteration rate was 70% (range 46% - 89%) with an expected complication rate of 13% (range 0% - 36%) for the MS group, 70% (range 89% - 46%) and 13% (range 0% - 36%) for the radiosurgery group. **CONCLUSIONS:** In the clinic setting, patients who might be offered surgery with a higher chance of BAVM obliteration are frequently offered SRS. Patient and operator preference may be a factor in that decision but it could explain low observed BAVM obliteration rates when treatment modality is left to patient or operator discretion. Future trials should assign therapy based on validated clinical decision tools.

27. Surgical Excision as Effective Therapy for Grade III Radiation Induced Imaging Changes associated with Adverse Radiation Effects Complicating Radiosurgical Treatment of Brain AVM

Ahilan Kailaya-Vasan, MBBS, BSc, MRCS, Daniel C. Walsh.

Neurosurgery, King's College Hospital, London, United Kingdom.

INTRODUCTION/PURPOSE: Grade III radiation induced imaging changes (RIIC) represent the imaging characteristics of the most severe Adverse Radiation Effects (AREs) - represented by severe imaging changes that cause midline shift. Such significant changes can occur following stereotactic radiosurgery for arteriovenous malformations (AVMs). They are an uncommon but potentially devastating complication. The current management for AREs is varied however there is a strong reliance on corticosteroid therapy. Our work reviewed the currently available treatment and demonstrates with our experience that early surgical excision of the treated nidus offers effective and rapid amelioration of symptoms.

METHODS: All grade III RIIC AREs identified in a neurovascular MDT between 2010 and 2016 were reviewed. Three refractory cases are presented.

RESULTS: Patient 1 was operated on after nine months of failed corticosteroid therapy with immediate symptomatic improvement. Patient 2 was operated on after five months with a good response however suffered a further bleed however remained stable. Patient 3 passed away after prolonged period of steroid therapy. Pt 3 did not represent a suitable candidate for surgical excision but the decision to treat with SRS merits reconsideration. The surgical management of two patients was successful, sparing the patients of symptoms and complications associated with corticosteroid therapy. The histology from these had features of radiation induced changes to the blood vessels and parenchyma. A literature review identified current and putative methods for managing AREs.

CONCLUSIONS: The review demonstrated that although a number of different medical therapies (e.g. bevacizumab) are put forward corticosteroid therapy remains the mainstay. The decision to operate was deferred in these cases while medical therapies were trialed and perhaps should be considered earlier given the profound improvement observed. Surgical management evidenced by our cases and those in the literature demonstrates the practice to be safe and definitive as contrasted to the long-term use of corticosteroids.

28. Revised Grading System for Arteriovenous Malformations in the Modern Microsurgical Era

Abdullah Feroze, Chibawanye L. Ene, Isaac J. Abecassis, Jason Barber, Louis J. Kim, Laligam N. Sekhar. Neurosurgery, University of Washington, Seattle, WA, USA.

INTRODUCTION/PURPOSE: The Spetzler-Martin grading system is a widely accepted classification system for the evaluation and treatment of brain arteriovenous malformations (bAVMs). Since its original description in 1986, the methods for treating bAVMs have evolved. [1] Therefore, corresponding indications for treatment merit re-evaluation. The ultimate goal of bAVM treatment is to obliterate the lesion with little or no morbidity. There is, however, currently no standard of care for bAVMs even with multiple treatment modalities available, with embolization, radiosurgery, and microsurgical resection administered individually or in combination. Herein, we propose a new classification system for bAVMs incorporating clinical and angiographic variables to guide management of ruptured and unruptured bAVMs.

METHODS: We evaluated 310 consecutive patients with ruptured and unruptured bAVMs treated at the University of Washington (Seattle, WA) between 2001-2015. The senior author designed a new classification system based on his experience. A scoring system was developed and validated based on lesion diameter, location (hemispheric, cerebellar or brainstem), depth (superficial or deep), and presence of dangerous angiographic features (i.e., perinidal aneurysms, the number and size of draining veins and venous stasis). Outcomes evaluated include the extent of bAVM obliteration and presence of temporary (lasting <6 months) or long-term morbidity (lasting >6 months).

RESULTS: Our proposed classification system will be compared to the Spetzler-Martin grades for the same cohort of patients. The results of our evaluation with statistical analysis will be presented.

[1] Spetzler RF, Martin NA. 1986. A proposed grading system for arteriovenous malformations. *J Neurosurg* 65(4): 476-483.

Table 1. Revised schema for classification of arteriovenous malformations.

Size (average diameter, cm)	<2.0 cm	
	2.0 – 3.9 cm	
	>3.9 cm	
Location	Supratentorial	Superficial only
		Superficial and deep
		Deep only
	Infratentorial	Superficial only
		Superficial and deep
		Deep only
Presence of flow-related or intranidal aneurysm		
Radiosurgery		
Embolization		



SILVERADO

Resort and Spa, Napa

A Dolce Resort



Dining

Two full service restaurants onsite – *Ad Lib* is a Thomas Keller Restaurant Group (TKRG) temporary pop-up restaurant, offering a classic American menu of traditional recipes prepared with the same quality ingredients and execution TKRG guests have come to expect (open seasonally). *The Grill at Silverado* is open for Breakfast, Lunch and Dinner and offers guests a first class casual dining experience with views of the golf course.

Golf

Two Championship Golf courses – The North course is rated one of the “Best Resort Courses” in California and is the new home to the Frys.com PGA FedEx Cup Series Tournament for 2014 and 2015. Golf Shop and Facilities includes a putting green and driving range. It also features a pro shop, equipment, cart rentals, and locker rooms.

Spa

The Spa at Silverado is a 16,000 square foot full service spa offering fitness, spa and salon services surrounded by tranquil garden courtyards and breathtaking scenic views offering both the novice and seasoned spa enthusiast a haven of absolute relaxation and healthy rejuvenation. The philosophy is quite simply to create joy for all guests.

Tennis

10 plexi-paved tennis courts – Lessons and equipment rental are available.
Reservations call: 707 257-5541

Nearby Wineries

William Hill Estate Winery
1761 Atlas Peak Road, Napa

Artesa Winery
1345 Henry Road, Napa

Robert Mondavi Winery
7801 St. Helena Hwy., Oakville

Whitehall Lane Winery
1563 St. Helena Hwy, St. Helena

Andretti Winery
4162 Big Ranch Rd, Napa,

Rutherford Ranch Winery
1680 Silverado Trail, St. Helena

Grgich Hills Estate
1829 St. Helena Highway, Rutherford

Silverado Vineyards
6121 Silverado Trail, Napa

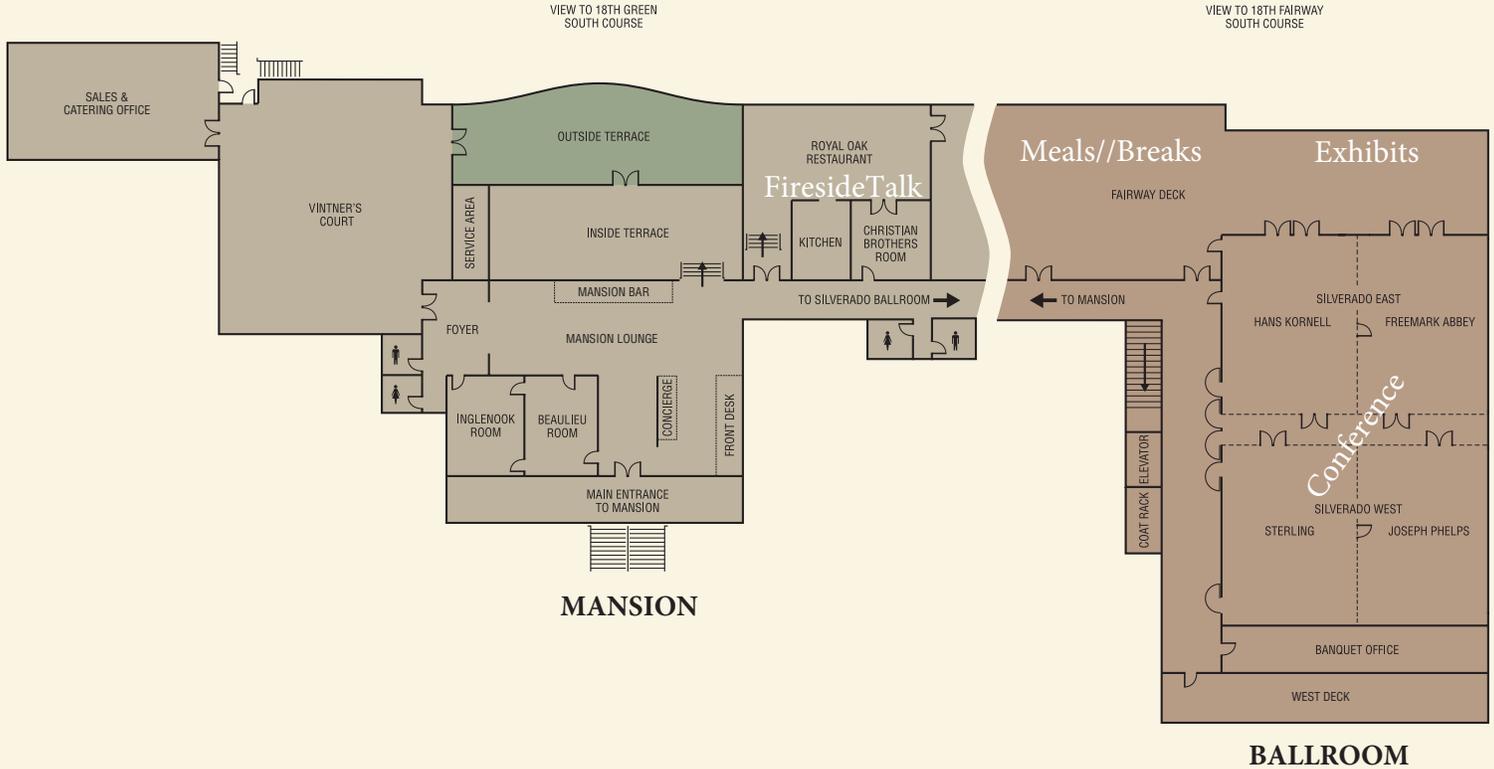
Pine Ridge Vineyards
6121 Silverado Trail, Napa



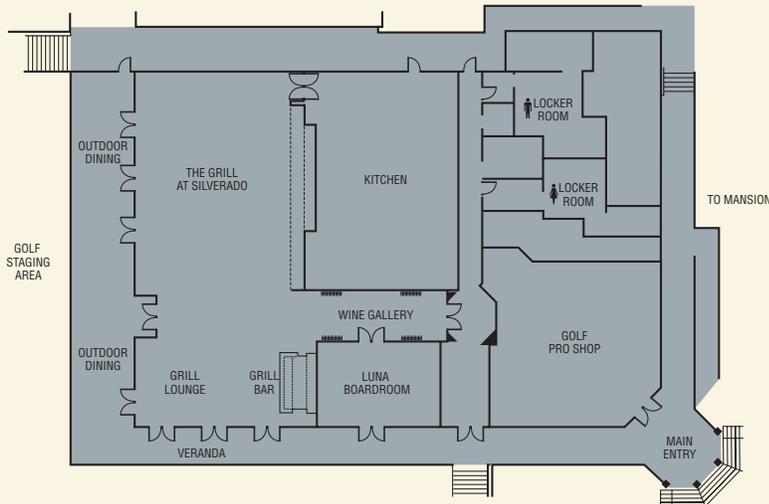
Special Events Floor Plans

SILVERADO

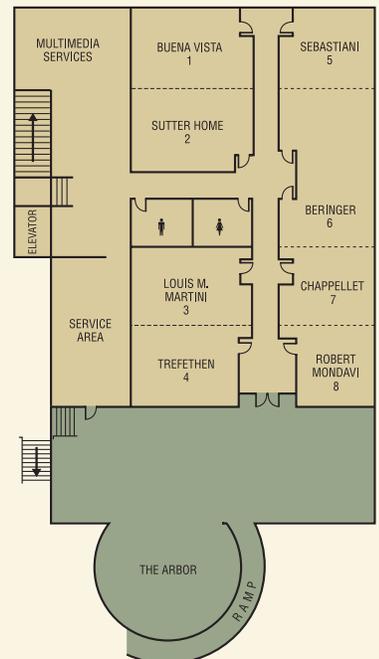
Resort and Spa
Napa



GOLF & GRILL BUILDING

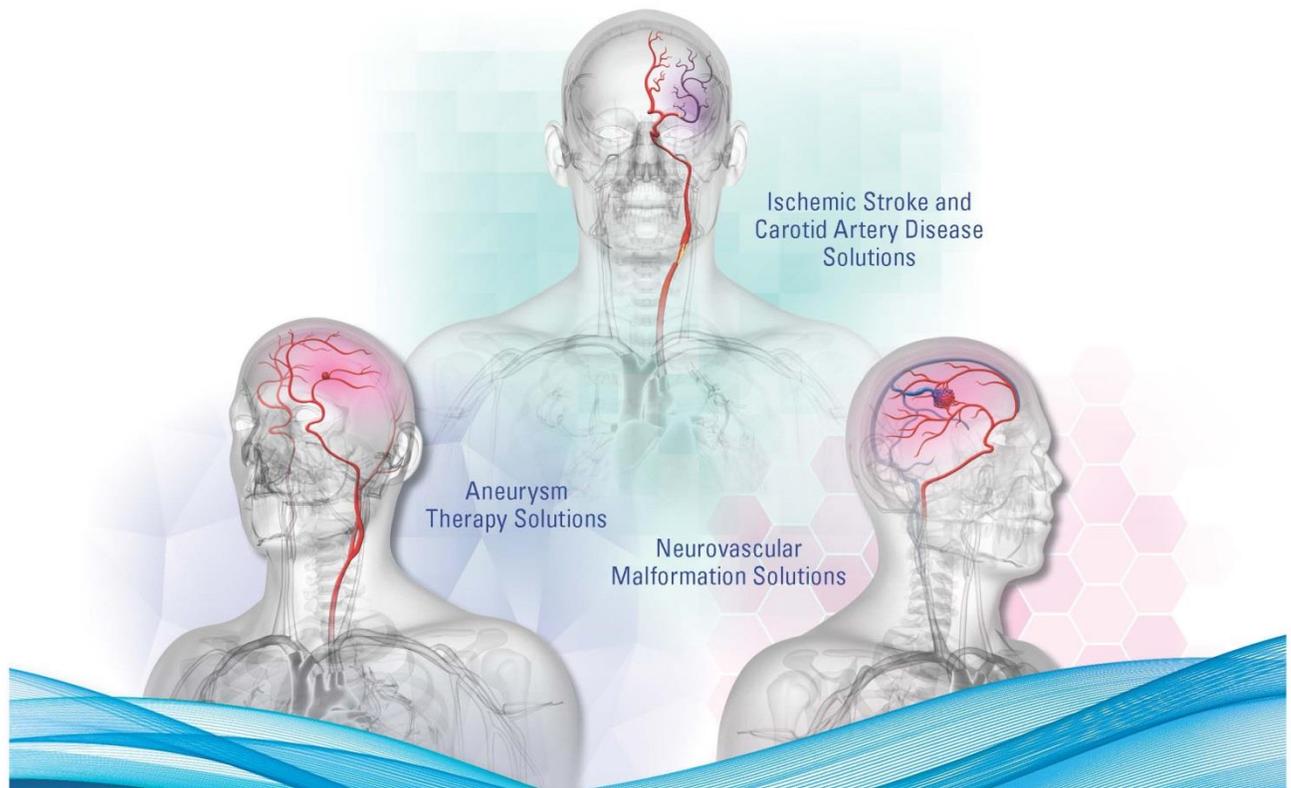


CONFERENCE ROOMS





*MicroVention® is a Proud Silver Sponsor of the
3rd World AVM Congress 2016*



A 360-Degree Approach to Performance Based Solutions

**Please visit our booth during the meeting to learn more about
MicroVention and our latest products.**

MICROVENTION is a registered trademark of MicroVention, Inc. Terumo is a registered trademark of Terumo Corporation.
© 2016 MicroVention, Inc.