Supplementary Table 6: Perfusion assessment in cerebral aneurysm surgery

Ref. No.	Author	Country	Journal	Year	Study design	Patient selection		Imaging techniques						Endpoint measures						Ref. detail
						Subject	N (cases)	Fluorogenic agent	Dose	Route	Timing	Imaging system	Quantitative measurement	Main endpoints	Imaging accuracy/success rate	Clinical impact, changes in intraoperative decision-making	Clinical impact, advantages in postoperative outcomes	Adverse effects	Learning curve	Cost analysis	Other comments	
1	Raabe	Germany	Neurosurgery	2003	Retrospective	Cerebral aneurysms	14	ICG	0.2–0.5 mg/kg	IV	Just before the observation	IC-View (Pulsion Medical Systems AG, Munich, Germany) & NIR-sensitive digital camcorder	NA	Visualization of aneurysms, cerebral arteries	100%	21% changes of surgical procedures	NA	None	NA	NA	Compared with postoperative DSA	Raabe A, Beck J, Gerlach R, Zimmermann M, Seifert V. Neurosurgery. 2003 Jan;52(1):132-9
2	Raabe	Germany	J Neurosurg	2005	Prospective	Cerebral aneurysms	114	ICG	25mg	IV	Just before the observation	Carl Zeiss microscope (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, cerebral arteries	90%	9% changes of surgical procedures	NA	None	NA	NA	Compared with intra or postoperative DSA	Raabe A, Nakaji P, Beck J, Kim LJ, Hsu FP, Kamerman JD, Seifert V, Spetzler RF. J Neurosurg. 2005 Dec;103(6):982-9
3	Raabe	Germany	Zentralbl Neurochir.	2005	Retrospective	Cerebral aneurysms	20	ICG	25mg	IV	Just before the observation	IC-PULSION (Pulsion Medical Systems AG, Munich, Germany), OPMI Vario (The Carl Zeiss Co., Oberkochen, Germany.)	NA	Visualization of aneurysms, cerebral arteries	100%	10% clip correction	NA	None	NA	NA		Raabe A, Beck J, Seifert V. Zentralbl Neurochir. 2005 Feb;66(1):1-6
4	Imizu	Japan	Minim Invasive Neurosurg.	2008	Retrospective	Cerebral aneurysms	13	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, cerebral arteries	100%	23% clip repositioning because of incomplete clipping	NA	None	NA	NA		Imizu S, Kato Y, Sangli A, Oguri D, Sano H. Minim Invasive Neurosurg. 2008 Aug;51(4):199-203
5	Ma	China	Clin Neurol Neurosurg	2009	Retrospective	Cerebral aneurysms	45	ICG	25mg	IV	Just before the observation	(Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, cerebral arteries	97.7%	18% changes of surgical procedures	1 case (2.4%) MCO	None	NA	NA	Compared with postoperative DSA	Ma CY, Shi JX, Wang HD, Hang CH, Cheng HL, Wu W. Clin Neurol Neurosurg. 2009 Dec;111(10):840-6
6	Li	China	Neurol India	2009	Retrospective	Cerebral aneurysms	120	ICG	25mg	IV	Just before the observation	Leica M525 OH4 (Leica Microsystems, Germany).	NA	Visualization of aneurysms, cerebral arteries	92.6%	7.5% clip repositioning/adjustment	2.5% residual aneurysms	None	NA	NA	Compared with postoperative DSA	Li J, Lan Z, He M, You C. Neurol India. 2009 Jul-Aug;57(4):453-9
7	Dashti	Finland	Surg Neurol	2009	Retrospective	Cerebral aneurysms	190	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, cerebral arteries	88%	NA	6% neck remnant. 6% branch occlusion	None	NA	NA	Compared with postoperative DSA, CTA, MRA	Dashti R, Laakso A, Niemelˆ, M, Porras M, Hernesniemi J. Surg Neurol. 2009 May;71(5):543-50
8	Fischer	Germany	Acta Neurochir (Wien)	2010	Retrospective	Cerebral aneurysms	43	ICG	0.5 mg/kg	IV	Just before the observation	OPMI Pentero, The Carl Zeiss Co., Oberkochen, Germany.	NA	Visualization of aneurysms, cerebral arteries	84% (overall)	NA	NA	None	NA	NA	Compared with postoperative DSA	Fischer G, Stadie A, Oertel JM. Acta Neurochir (Wien). 2010 Sep;152(9):1519-25
9	Khurana	Australia	Br J Neurosurg	2010	Retrospective	Cerebral aneurysms	27	ICG	0.15 mg/kg	IV	Just before the observation	Leica M525 OH4 & near-infrared camera FL 800 (Leica Microsystems, Switzerland).	NA	Visualization of aneurysms and cerebral arteries, surgical decision-making	74%	26% changes of surgical procedures (2% false reassurance)	NA	None	NA	NA		Khurana VG, Seow K, Duke D. Br J Neurosurg. 2010 Apr;24(2):163-72
10	Wang	China	Neurosurg Rev	2010	Retrospective	Cerebral aneurysms	129	ICG	25mg	IV	Just before the observation	Pentero(Carl Zeiss, Oberkochen, Germany). Leica OH4 (Leica Microsystems, Switzerland).	NA	Visualization of aneurysms and cerebral arteries, surgical decision-making	99%	2% changes of surgical procedures	1 branch occlusion. No neck remnant	None	NA	NA	Compared with intraoperative DSA	Wang S, Liu L, Zhao Y, Zhang D, Yang M, Zhao J. Neurosurg Rev. 2010 Apr;34(2):209-15.
11	Jing	China	J Clin Neurosci.	2010	Retrospective	Cerebral aneurysms	42	ICG	25mg	IV	2-5 minutes before the observation	Leica OH3 FL800 fluorescence system, Wetzlar, Germany	NA	Visualization of aneurysms, cerebral arteries	100%	NA	NA	None	NA	NA	Compared with postoperative DSA, CTA, MRA	Jing Z, Ou S, Ban Y, Tong Z, Wang Y. J Clin Neurosci. 2010 Jan;17(1):26-8
12	Murai	Japan	World Neurosurg	2011	Retrospective	Cerebral aneurysms	5	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI PenteroINFRARED 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of cerebral arteries	100%	NA	NA	None	NA	NA		Murai Y, Adachi K, Takagi R, Koketsu K, Matano F, Teramoto A. World Neurosurg. 2011 Nov;76(5):477.e7-477.e10.
13	Oda	Japan	J Clin Neurosci	2011	Retrospective	Cerebral aneurysms	39	ICG	0.2–0.5 mg/kg	IV	Just before the observation	surgical microscope (Carl Zeiss, Oberkochen, Germany)	Fluorescence intensity	Visualization of aneurysms, cerebral arteries	100%	8% clip repositioning	NA	None	NA	NA	Compared with postoperative CTA	Oda J, Kato Y, Chen SF, Sodhiya P, Watabe T, Imizu S, Oguri D, Sano H, Hirose Y. J Clin Neurosci. 2011 Aug;18(8):1097-100
14	Chen	Japan	Surg Neurol Int	2011	Retrospective	Cerebral aneurysms	45	ICG	12.5 mg	IV	Just before the observation	surgical microscope & FLOW 800 (Carl Zeiss, Oberkochen, Germany)	Fluorescence intensity	Visualization of aneurysms, cerebral arteries	100%	8% clip repositioning	No branch stenosis or neck remnant	None	NA	NA	Compared with postoperative CTA	Chen SF, Kato Y, Oda J, Kumar A, Watabe T, Imizu S, Oguri D, Sano H, Hirose Y. Surg Neurol Int. 2011 Mar 31;2:42
15	Gruber	Austria	Neurosurgery	2011	Prospective	Cerebral aneurysms	104	ICG	2.5-25 mg	IV	Just before the observation	Pentero, The Carl Zeiss Co., Oberkochen, Germany. Leica M720-FL800; Leica Microsystems GmbH, Wechsler, Germany)	NA	Visualization of aneurysm and cerebral arteries, surgical decision-making	97.5%	24.4% clip repositioning	NA	NA	NA	NA	Compared with intraoperative DSA	Gruber A, Dorfer C, Standhardt H, Bavinzski G, Knosp E. Neurosurgery. 2011 Mar;68(3):657-73
16	Esposito	The Netherlands	Neurosurgery	2012	Retrospective	Cerebral aneurysms	7	ICG	25mg	IV	Just before the observation	OPMI® PenteroTM (Carl Zeiss, Oberkochen, Germany)	NA	Identification of cortical recipient vessels to perform selective-targeted EC-IC bypass	100%	NA	NA	None	NA	NA	Temporary clip occlusion	Esposito G, Durand A, Van Doormaal T, Regli L. Neurosurgery. 2012 Dec;71(2 Suppl Operative):ons274-84
17	Schubert	Austria	Neurosurgery	2012	Retrospective	Cerebral aneurysms	11	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI® Pentero 900, FLOW 800, (Carl Zeiss, Oberkochen, Germany)	Fluorescence intensity	Perfusion changes early after SAH	The velocity of signal change in SAH patients was significantly lower in all 3 compartments (P < .001, P < .01, P < .001, respectively), as was the peak fluorescence intensity (P < .001)	NA	NA	None	NA	NA	Cortical perfusion study	Schubert GA, Seiz-Rosenhagen M, Ortler M, Czabanka M, Scheufler KM, Thomé C. Neurosurgery. 2012 Dec;71(2 Suppl Operative):ons260-7
18	Schnell	Germany	Acta Neurochir (Wien).	2012	Prospective	Cerebral aneurysms	10	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI® Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of cerebral arteries	90%	NA	NA	None	NA	NA	Compared with intraoperative CTA	Schnell O, Morhard D, Holtmannsp ?tter M, Reiser M, Tonn JC, Schichor C. Acta Neurochir (Wien). 2012 Oct;154(10):1861-8.
19	Nishiyama	Japan	J Neurosurg	2012	Retrospective	Cerebral aneurysms	3	ICG	25mg	IV	Just before the observation	light source (Visera CLV-S40Pro, Olympus) endoscopes (A70940A, A70941, Olympus) video processor (Visera OTV-S7Pro, Olympus)	NA	Visualization of aneurysms, cerebral arteries	100%	NA	NA	None	NA	NA	Endoscopic system	Nishiyama Y, Kinouchi H, Senbokaya N, Kato T, Kanemaru K, Yoshioka H, Horikoshi T. J Neurosurg. 2012 Aug;117(2):302-8.
20	Rodríguez-Hernández	US	Neurosurgery	2012	Retrospective	Cerebral aneurysms	3	ICG	NA	IV	NA	NA	NA	Visualization of cerebral arteries	100%	NA	NA	None	NA	NA		Rodríguez-Hernández A, Lawton MT. Neurosurgery. 2012 Jun;70(2 Suppl Operative):209-20
21	Gürer	US	Surg Neurol Int	2013	Retrospective	Cerebral aneurysms	2	ICG	NA	IV	NA	NA	NA	Visualization of arterial perfusion after temporary clipping	100%	NA	NA	NA	NA	NA	Compared with postoperative angiography	Gürer B, Antar V, Cikla U, Bauer A, Baskaya MK. Surg Neurol Int. 2013 Sep 25;4:122

Supplementary Table 6: Perfusion assessment in cerebral aneurysm surgery

Ref. No.	Author	Country	Journal	Year	Study design	Patient selection		Imaging techniques						Endpoint measures							Ref. detail
						Subject	N (cases)	Fluorogenic agent	Dose	Route	Timing	Imaging system	Quantitative measurement	Main endpoints	Imaging accuracy/success rate	Clinical impact, changes in intraoperative decision-making	Clinical impact, advantages in postoperative outcomes	Adverse effects	Learning curve	Cost analysis	Other comments	
22	Özgiray	US	Clin Neurol Neurosurg.	2013	Retrospective	Cerebral aneurysms	109	ICG	0.2–0.5 mg/kg	IV	Just before the observation	M720-FL800 (Leica Microsystems GmbH, Wechsler, Germany)	NA	Visualization of vessel patency and aneurysm obliteration	93.5% (4.5% false negative, 0.9% false positive)	NA	NA	None	NA	NA	Compared with intraoperative puncture & postoperative DSA	Özgiray E, Akätlee E, Patel N, Baggott C, Bozkurt M, Niemann D, Başkaya MK. Clin Neurol Neurosurg. 2013 Jul;115(7):870-8.
23	Son	Korea	J Cerebrovasc Endovasc Neurosurg	2013	Retrospective	Cerebral aneurysms	16	ICG	25mg	IV	Just before the observation	OPMI® PenteroTM, The Carl Zeiss Co., Oberkochen, Germany. GomPlayer (Ver. 2.1.36, Gretech Corp., Seoul, KR), ImageJ (Ver. 1.42q, http://rsb.info.nih.gov/ij/, NIH, USA)	Fluorescence intensity	Feasibility	NA	NA	NA	NA	NA	NA		Son YJ, Kim JE, Park SB, Lee SH, Chung YS, Yang HJ. J Cerebrovasc Endovasc Neurosurg. 2013 Jun;15(2):76-84.
24	Washington	US	J Neurosurg	2013	Retrospective	Cerebral aneurysms	49	ICG	25 mg	IV	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany) or Leica Fluorescence Module (Leica Microsystems, Wetzlar, Germany)	NA	Identification of aneurysmal remnant or unwanted vessel stenosis or occlusion and incidence of clip adjustment post-IA clip	75.50%	Clip adjustment rate was 4.1%; discordance rate requiring clip adjustment was 14.3%	NA	NA	NA	NA	IA should remain the gold standard, but can be supplemented by ICG-VA	Washington CW, Zipfel GJ, Chicoine MR, Dereboy CP, Rich KM, Moran CJ, Cross DT, Dacey RG Jr. J Neurosurg. 2013 Feb;118(2):420-7. doi: 10.3171/2012.10.JNS11818. Epub 2012 Nov 16.
25	Sharma	US	World Neurosurg	2014	Retrospective	Cerebral aneurysms	112	ICG	25mg	IV	Just before the observation	OPMI® Pentero, flow 800, Carl Zeiss	NA	Completeness of aneurysm occlusion and parent and branching vessel compromise, clip repositioning rate	96%	8% clip repositioning	NA	NA	NA	NA	Compared with postoperative DSA.	Sharma M, Ambekar S, Ahmed O, Nixon M, Sharma A, Nanda A, Guthikonda B. World Neurosurg. 2014 Nov;82(5):e607-13.
26	Caplan	US	Neurosurgery	2014	Retrospective	Cerebral aneurysms	37 (+60 control)	ICG	12.5 mg	IV	Just before the observation	OPMI® Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms (additional benefit of ICG-IV to routine IA)	89.2% (4 false negatives requiring clip adjustments)	NA	NA	NA	NA	NA	Compared with intraoperative DSA	Caplan JM, Sankey E., Yang W, Radvany MG, Colby GP, Coon AL, Tamargo RJ, Huang J. Neurosurgery. 2014 Oct;75(4):437-43
27	Hardesty	US	J Clin Neurosci	2014	Retrospective	Cerebral aneurysms	100	ICG	NA	IV	NA	NA	NA	Clip repositioning rate, operative outcomes, cost	NA	4.4% clip repositioning (6% by DSA only)	No differences in the rate of perioperative stroke or rate of false-negative studies	None	NA	The per-patient cost of intraoperative imaging within the DSA era was significantly higher than in the ICG era	Compared with surgeries with intraoperative DSA only	Hardesty DA, Thind H, Zabramski JM, Spetzler RF, Nakaji P. J Clin Neurosci. 2014 Aug;21(8):1377-82.
28	Murai	Japan	Clin Neurol Neurosurg.	2014	Retrospective	Cerebral aneurysms	13	ICG	0.3 mg/kg	IV	Just before the observation	Carl Zeiss Surgical Microscope OPMI PenteroINFRARED 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of cerebral arteries (relationship between the distal M4 and proximal M2)	84.6%	NA	NA	None	NA	NA	Temporary parent artery clip occlusion	Murai Y, Mizunari T, Koketsu K, Tateyama K, Kobayashi S, Umeoka K, Teramoto A, Morita A. Clin Neurol Neurosurg. 2014 Apr;119:70-4.
29	Roessler	Germany	Neurosurg Focus	2014	Retrospective	Cerebral aneurysms	232	ICG	25mg	IV	Just before the observation	Carl Zeiss Surgical Microscope OPMI Pentero, INFRARED 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, clip repositioning rate	90.1% (9.1% false negative for neck remnant)	9% clip repositioning	Postoperative coil embolization for neck remnant was needed in 1 patient	NA	NA	NA	Compared with postoperative DSA	Roessler K, Krawagna M, D?rfler A, Buchfelder M, Ganslandt O. Neurosurg Focus. 2014 Feb;36(2):E7
30	Della Puppa	Italy	Clin Neurol Neurosurg.	2014	Retrospective	Cerebral aneurysms	26	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI® Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, clip repositioning rate	96.2%	9% clip repositioning by ICG-VA	1 postoperative neck remnant	None	NA	NA	Compared with postoperative DSA/CTA	Della Puppa A, Volpin F, Gioffre G, Rustemi O, Troncon I, Scienza R. Clin Neurol Neurosurg. 2014 Jan;116:35-40
31	Lai	Australia	J Clin Neurosci.	2014	Retrospective	Cerebral aneurysms	91	ICG	25mg	IV	Just before the observation	OPMI® Pentero, flow 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, clip repositioning rate	94% (4% no benefit and 2% misleading)	6% critical changes of intraoperative strategies	3.3% postoperative ischemic complications (vs. 7.7% in historical control, P < 01001)	1.1% (transient decrease of O2 saturation)	NA	NA	Compared with historical control without a use of ICGVAG	Lai LT, Morgan MK. J Clin Neurosci. 2014 Jan;21(1):67-72.
32	Liu	China	Turk Neurosurg	2014	Retrospective	Cerebral aneurysms	65	ICG	25mg	IV	Just before the observation	Leica OH4 (Leica Microsystems, Wetzlar, Germany) , OPMI ® Pentero, flow 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysms, cerebral arteries	100%	NA	NA	None	NA	NA	Compared with postoperative imaging	Liu J, Li X, Sun S, Wang Y, Zang P. Turk Neurosurg. 2014;24(3):319-22.
33	Hardesty	US	J Clin Neurosci	2014	Retrospective	Cerebral aneurysms	100 (+100 control)	ICG	NA	NA	NA	NA	NA	Rates of perioperative stroke, postoperative aneurysm residuals, and parent vessel stenosis	99% (rate of 1% of false negatives)	Clip repositioning rates, rates of perioperative stroke, and rates of false negatives were similar between patients who received DSA and patients who received ICG	NA	NA	NA	DSA cost much more than ICG-VA	Replacing DSA with ICG-VA is typically safe and effective	Hardesty DA, Thind H, Zabramski JM, Spetzler RF, Nakaji P. J Clin Neurosci. 2014 Aug;21(8):1377-82. doi: 10.1016/j.jocn.2014.02.00
34	Roessler	Germany	Neurosurg Focus	2014	Retrospective	Cerebral aneurysms	236	ICG	25 mg	IV	NA	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Qualify the efficacy and advantages of ICG-VA in aneurysm surgery	Around 90%	9% clip repositioning; 4.5% required additional clip for residual perfusion; overall 15% intraoperative clip modification rate	9.1% neck remnants were found postoperatively	NA	NA	NA	Digital subtraction angiography is essential to postoperative assessment	Roessler K, Krawagna M, Dorfler A, Buchfelder M, Ganslandt O. Neurosurg Focus. 2014 Feb;36(2):E7. doi: 10.3171/2013.11.FOCUS13475.
35	Sato	Japan	Acta Neurochir (Wien)	2015	Retrospective	Cerebral aneurysms	10	ICG	0.25mg/kg	IV	NA	OPMI® Pentero 900 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysm and vessels	100%	50% additional procedures	NA	None	NA	NA		Sato T, Suzuki K, Sakuma J, Takatsu N, Kojima Y, Sugano T, Saito K. Acta Neurochir (Wien). 2015 Sep;157(8):1295-301
36	Pahl	Brazil	Arq Neuropsiquiatr.	2015	Retrospective	Cerebral aneurysms	56	ICG	25mg	IV	Just before the observation	Carl Zeiss Surgical Microscope OPMI Pentero. IR 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysm and vesselsm, clip adjustment rates	96.7% (3.3% false negative occlusion rate)	3.2% clip repositioning	3.3% (2 case) false negative occlusion rate.	None	NA	NA	Compared with direct puncture	Pahl FH, Oliveira MF, Brock RS, Lucio JE. Arq Neuropsiquiatr. 2015 Jul;73(7):607-10
37	Doss	US	Interv Neurol	2015	Retrospective	Cerebral aneurysms	47	ICG	NA	IV	NA	NA	NA	Visualization of aneurysms, adequacy of the clipping.	84.3% (9 false negative for neck remnant)	NA	NA	NA	NA	NA	Compared with postoperative DSA.	Doss VT, Goyal N, Humphries W, Holt D, Arthur A, Elijovich L. Interv Neurol. 2015 Jul;3(3-4):129-34
38	Lane	US	J Neurosurg	2015	Prospective	Cerebral aneurysms	22	ICG, FL	FL: 75 mg. ICG 25mg	IV	Just before the observation	Carl Zeiss OPMI Pentero 900 (Carl Zeiss, Oberkochen, Germany)	NA	Aneurysm exclusion and the patency of adjacent arteries	FL-VA provided superior detail of small arteries than ICG-VA in 32% of the cases	NA	NA	NA	NA	NA		Lane B, Bohnstedt BN, Cohen-Gadol AA. J Neurosurg. 2015 Mar;122(3):618-26.
39	Murai	Japan	Neurol Med Chir (Tokyo)	2015	Retrospective	Cerebral aneurysms	3	ICG	0.3mg/kg	IV	Just before the observation	OPMI® PenteroTM (Carl Zeiss, Oberkochen, Germany)	Fluorescence intensity	Visualization of aneurysms, the distal/parent artery	100%	NA	NA	None	NA	NA	Temporary clip occlusion.	Murai Y, Mizunari T, Koketsu K, Tateyama K, Kobayashi S, Morita A, Teramoto A. Neurol Med Chir (Tokyo). 2015;55(8):683-8.
40	Murai	Japan	Neurosurg Rev	2016	Retrospective	Cerebral aneurysms	13	ICG	0.2–0.5 mg/kg	IV	Just before the observation	FLOW800 & OPMI Pentero 900 (Carl Zeiss, Oberkochen, Germany)	Time-intensity curves (FLOW800)	Detection of cerebral blood flow direction	100%	NA	NA	None	NA	NA		Murai Y, Nakagawa S, Metano F, Shirokane K, Teramoto A, Morita A. Neurosurg Rev. 2016 Oct;39(4):685-90.
41	Li	China	Med Sci Monit	2016	Retrospective	Cerebral aneurysms	28	ICG	25mg	IV	Just before the observation	Zeiss fluorescence microscope	NA	Visualization of aneurysm and vessels	100%	10.7% clip repositioning	NA	NA	NA	NA		Li Z, Zhang G, Huang G, Wang Z, Tan H, Liu J, Li A. Med Sci Monit. 2016 Feb 4;22:373-9.

Supplementary Table 6: Perfusion assessment in cerebral aneurysm surgery

Ref. No.	Author	Country	Journal	Year	Study design	Patient selection		Imaging techniques						Endpoint measures							Ref. detail
						Subject	N (cases)	Fluorogenic agent	Dose	Route	Timing	Imaging system	Quantitative measuremen	Main endpoints	Imaging accuracy/success rate	Clinical impact, changes in intraoperative decision-making	Clinical impact, advantages in postoperative outcomes	Adverse effects	Learning curve	Cost analysis	Other comments	
42	Kakucs	Romania	World Neurosurg	2017	Retrospective	Cerebral aneurysms	10	FL (Fluorescein)	500mg	IV	Just before the observation	OPMI® Pentero900 (Carl Zeiss, Oberkochen, Germany)	NA	Patency of the arteries adjacent to the aneurysm.	100%	NA	NA	Transient yellowing of the skin in all patients	NA	NA		Kakucs C, Florian IA, Ungureanu G, Florian IS. World Neurosurg. 2017 Sep;105:406-411
43	Kumar	India	J Neurosci Rural Pract.	2017	Prospective	Cerebral aneurysms	30	ICG	0.2–0.5 mg/kg	IV	Just before the observation	NA	NA	Occlusion of aneurysms	Sensitivity 91.7%, 6.5% false negative occlusion rate	25.8% clip adjustment	NA	None	NA	NA	Compared with postoperative DSA.	Kumar V, Jagetia A, Singh D, Srivastava AK, Tandon MS. J Neurosci Rural Pract. 2017 Jul-Sep;8(3):342-345.
44	Matano	Japan	Oper Neurosurg (Hagerstown)	2017	Prospective	Cerebral aneurysms	18	ICG, FL	FL 250 mg. ICG 12.5mg	IV	Just before the observation	Carl Zeiss OPMI Pentero 900 (Carl Zeiss, Oberkochen, Germany) and Flow 800. Aquacosmos9 (Hamamatsu Photonics Co.; Shizuoka, Japan) endoscopic (LAP-2C; Korea Electrotechnology Research	Fluorescence intensity	Visualizability of the cerebral arteries	Thick-walled artery, such as parent artery (P = .0017) and STA (P = .0182), was more significantly visualized by ICG-VAG than FL-VAG.	NA	NA	None	NA	NA	Compared with Fluorescein-videoangiography	Matano F, Mizunari T, Murai Y, Kubota A, Fujiki Y, Kobayashi S, Morita A. Oper Neurosurg (Hagerstown). 2017 Jan 1;13(3):361-366.
45	Cho	Korea	World Neurosurg	2017	Retrospective	Cerebral aneurysms	10	ICG	0.3–0.4 mg/kg	IV	Just before the observation	Institute,Seoul, Korea) , microscope (Leica M720 OH5 and FL800; Leica Microsystems, Wetzlar, Germany)	NA	Visualizability of the cerebral arteries	100% visualization by endoscopic system	40% clip adjustment	Frontal palsy (1) and anosmia (1)	None	NA	NA	Comparison between microscopic system and endoscopic system	Cho WS, Kim JE, Kang HS, Ha EJ, Jung M, Lee C, Shin BI, Kang U. World Neurosurg. 2017 Apr;100:316-324.
46	Feletti	Japan	World Neurosurg	2017	Retrospective	Cerebral aneurysms	5	ICG	12.5 mg	IV	Just before the observation	OPMI® Pentero, flow 800 (Carl Zeiss, Oberkochen, Germany)	NA	Visualization of aneurysm and vessels	100%	NA	NA	NA	NA	NA		Feletti A, Wang X, Tanaka R, Yamada Y, Suyama D, Kawase T, Sano H, Kato Y. World Neurosurg. 2017 May;99:572-579.
47	Marbacher	Switzerland	J Neurosurg	2018	Retrospective	Cerebral aneurysms	120	ICG	NA	IV	NA	NA	NA	The need for intraoperative clip readjustment	94%	11% clip repositioning	ICG and 3DDSA concordance rate	NA	NA	NA	Compared with intraoperative 3DDSA. Discordance: 71.4 % acom.	Marbacher S, Mendelowitsch I, Gr?ter BE, Diepers M, Remonda L, Fandino J. J Neurosurg. 2018 Jul 13;131(1):64-71.
48	Della Puppa	Italy	World Neurosurg	2018	Retrospective	Cerebral aneurysms	85	ICG	NA	IV	Just before the observation	OPMI Pentero with Infrared 800 (Carl Zeiss, Meditec, Germany)	NA	Rate of aneurysm exclusion and postoperative occurrence of ischemic injury.	98.8%, NPV 98.8% (one false negative remnant neck)	8.3% clip repositioning	2.1% postoperative symptomatic ischemic injury	None	NA	NA	Compared with postoperative CTA	Della Puppa A, Rossetto M, Volpin F, Rustemi O, Grego A, Gerardi A, Ortolan R, Causin F, Munari M, Scienza R. World Neurosurg 2018 May;113:e336-e344.
49	Bozkurt	Turkey	Turk Neurosurg	2018	Retrospective	Cerebral aneurysms	196	ICG	0.2–0.5 mg/kg	IV	Just before the observation	OPMI Pentero 900 (Carl Zeiss, Oberkochen, Germany)	NA	Aneurysm neck remnants and vessel patency	95.2%. 1.6% false negative occlusion rate	6.1% clip repositioning	NA	None	NA	NA	Compared with direct puncture. 0.8% neck remnant rate.	Bozkurt M, Ozgural O, Kahilogullari G, Eroglu U, Dogan I, Sekmen H, Egemen N. Turk Neurosurg. 2018;28(6):970-978.
50	Gekka	Japan	Acta Neurochir (Wien)	2018	Retrospective	Cerebral aneurysms	89	ICG	0.1 mg/kg	IV	Just before the observation	Carl Zeiss OPMI Pentero 900 (Carl Zeiss, Oberkochen, Germany)	NA	Occlusion of aneurysms	91.6%. 8.4% false negative occlusion rate	6.5% additional clip placement	8.4% false negative occlusion rate. Wall thickness around the neck was greater.	NA	NA	NA	Confirmed by direct puncture	Gekka M, Nakayama N, Uchino H, Houkin K. Acta Neurochir (Wien). 2018 Feb;160(2):269-276.
51	Fong	Taiwan	World Neurosurg	2018	Retrospective	Cerebral aneurysms	24	ICG	25 mg	IV	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Rate of clip repositioning	82.9%	17.1% clip repositioning	NA	None	NA	NA	Compared with intraoperative 3DDSA.	Fong YW, Hsu SK, Huang CT, Hsieh CT, Chen MH, Huang JS, Chang CJ, Su IC. World Neurosurg. 2018 Jun;114:e573-e580.
52	Nakagawa	Japan	World Neurosurg	2018	Retrospective	Cerebral aneurysms	37	ICG	0.3 mg/kg	IV	Just before the observation	Carl Zeiss OPMI Pentero 900 and Flow 800 (Carl Zeiss, Oberkochen, Germany)	Time-intensity curves (FLOW800)	Patency of anastomosis	89.7%	NA	NA	None	NA	NA		Nakagawa S, Murai Y, Matano F, Ishisaka E, Morita A. World Neurosurg. 2018 Feb;110:e699-e709.
53	Fischer	Germany	J Neurosurg	2018	Retrospective	Cerebral aneurysms	95	ICG	0.5 mg/kg (both imaging techniques)	IV	Just before the observation	For endoscope-integrated ICG-VA: OPMI Pentero (Carl Zeiss, Oberkochen, Germany); for endoscope-integrated ICG-VA: near-infrared endoscopic system (Karl Storz GmbH)	NA	Efficacy of endoscope-integrated ICG-VA vs. that of microscope-integrated ICG-VA in evaluating occlusion and blood flow	82% for microscope-integrated ICG-VA and 86.9% for endoscope-integrated ICG-VA	Endoscope-integrated ICG-VA was more effective than microscope-integrated ICG-VA at evaluating occlusion and blood flow and preventing remnants and residuals	Small ischemic infarctions in 6.5%	NA	NA	NA	Endoscope-integrated ICG-VA provides additional information	Fischer G, Rediker J, Oertel J. J Neurosurg. 2018 Oct 1:1-10. doi: 10.3171/2018.4.JNS172650.
54	Munakomi	Nepal	F1000Res	2018	Prospective	Cerebral aneurysms	40	ICG	NA	NA	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	Time lag for appearance of dye and absorption intensity	Predictive value of intraoperative FLOW 800 vascular map of postoperative vasospasm and delayed cerebral ischemia	NA	NA	The model showed good prediction of postoperative vasospasm from the absorption intensity of the ICG dye and CT Fisher grading	NA	NA	NA		Munakomi S, Poudel D. F1000Res. 2018 Aug 3;7:1188. doi: 10.12688/f1000research.15627.1.
55	Seng	Japan	Asian J Neurosurg	2018	Retrospective	Cerebral aneurysms	9	ICG	NA	IV	NA	NA	NA	Surgical outcome of unruptured basilar tip aneurysms treated by clipping	NA	NA	Oculomotor nerve palsy in two patients (resolved spontaneously)	NA	NA	NA	ICG imaging improves the safety of the procedure	Seng LB, Yamada Y, Rajagopal N, Mohammad AA, Teranishi T, Miyatani K, Kawase T, Kato Y. Asian J Neurosurg. 2018 Oct-Dec;13(4):1148-1157. doi: 10.4103/ajns.AJNS_159_18.
56	Rennert	US	Oper Neurosurg (Hagerstown)	2019	Retrospective	Cerebral aneurysms	3	ICG	0.2 mg/kg	IV	Just before the observation	Kinevo & Pentero (Carl Zeiss, Oberkochen, Germany), FLOW 800	Time-intensity curves (FLOW800)	Occlusion of aneurysms, cortical perfusion	100%	1/3 clip repositioning	NA	NA	NA	NA		Rennert RC, Strickland BA, Ravina K, Bakhsheshian J, Fredrickson V, Carey J, Russin JJ. Oper Neurosurg (Hagerstown). 2019 May 1;16(5):583-592
57	Tajsic	United Kingdom	Acta Neurochir (Wien)	2019	Retrospective	Cerebral aneurysms	212 (200 control)	ICG	NA	NA	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Reduction in vascular compromise or injury during clipping from use of ICG-VA	NA	Procedural vascular error rate was 9.5% in group that did not receive ICG-VA and 3.3% in the group that received ICG-VA	NA	NA	"Interestingly, the procedural errors were distributed evenly over time indicating that there is no learning curve associated with the use of ICG-VA."	NA	Use of ICG-VA reduces technical errors	Tajsic T, Cullen J, Gailfoyle M, Helmy A, Kirollos R, Kirkpatrick P, Trivedi R. Acta Neurochir (Wien). 2019 Nov;161(11):2397-2401. doi: 10.1007/s00701-019-04029-6.
58	Goertz	Germany	World Neurosurg	2019	Retrospective	Cerebral aneurysms	54	ICG	10 mg	IV	Just before the observation	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	Maximum fluorescence intensity, time to peak, delay, arterioarterial transit time, and arteriovenous transit time before and after clip placement	Reference values for FLOW 800 parameters before and after clipping and FLOW 800 guidance of intraoperative decisions	NA	Clip repositioning rate was 17.9%	Two cases of clip stenosis may have been missed under standard ICG-VA	NA	NA	NA		Goertz L, Hof M, Timmer M, Schulte AP, Kabbasch C, Krischek B, Stavrinou P, Reiner M, Goldbrunner R, Brinker G. World Neurosurg. 2019 Nov;131:e192-e200. doi: 10.1016/j.wneu.2019.07.113.
59	Kannan	Japan	Asian J Neurosurg	2019	Retrospective	Cerebral aneurysms	347	ICG	NA	NA	NA	OPMI Pentero (Carl Zeiss, Oberkochen, Germany)	NA	Validate in-house protocol of tools used during clipping surgery	NA	NA	NA	NA	NA	NA	Combining intraoperative imaging tools optimizes surgery outcomes	Kannan S, Yamada Y, Miyatani K, Teranishi T, Marathi AR, Mohan K, Kawase T, Kato Y. Asian J Neurosurg. 2019 Jul-Sep;14(3):773-779. doi: 10.4103/ajns.AJNS_65_19.

Supplementary Table 6: Perfusion assessment in cerebral aneurysm surgery

Ref. No.	Author	Country	Journal	Year	Study design	Patient selection		Imaging techniques						Endpoint measures				Adverse effects	Learning curve	Cost analysis	Other comments	Ref. detail
						Subject	N (cases)	Fluorogenic agent	Dose	Route	Timing	Imaging system	Quantitative measuremen	Main endpoints	Imaging accuracy/success rate	Clinical impact, changes in intraoperative decision-making	Clinical impact, advantages in postoperative outcomes					
60	Rennert	US	J Clin Neurosci	2019	Retrospective	Cerebral aneurysms	10	ICG	0.2 mg/kg	IV	NA	FLOW800, Pentero, and Kinevo (Carl Zeiss, Oberkochen, Germany)	NA	Postoperative ischemia	NA	NA	20% of cases experienced ischemia	NA	NA	NA	Intraoperative ICG-based flow analyses can assist in assessing the risk of ischemia	Rennert RC, Strickland BA, Kenma K, Brandel MG, Bakhsheshian J, Fredrickson V, Carey J, Russin JJ. J Clin Neurosci. 2019 Sep;67:191-197. doi: 10.1016/j.jocn.2019.06.036.

NA, not available or not assessed