Balloon Pulmonary Angioplasty (BPA)

Hiromi Matsubara
Okayama Medical Center

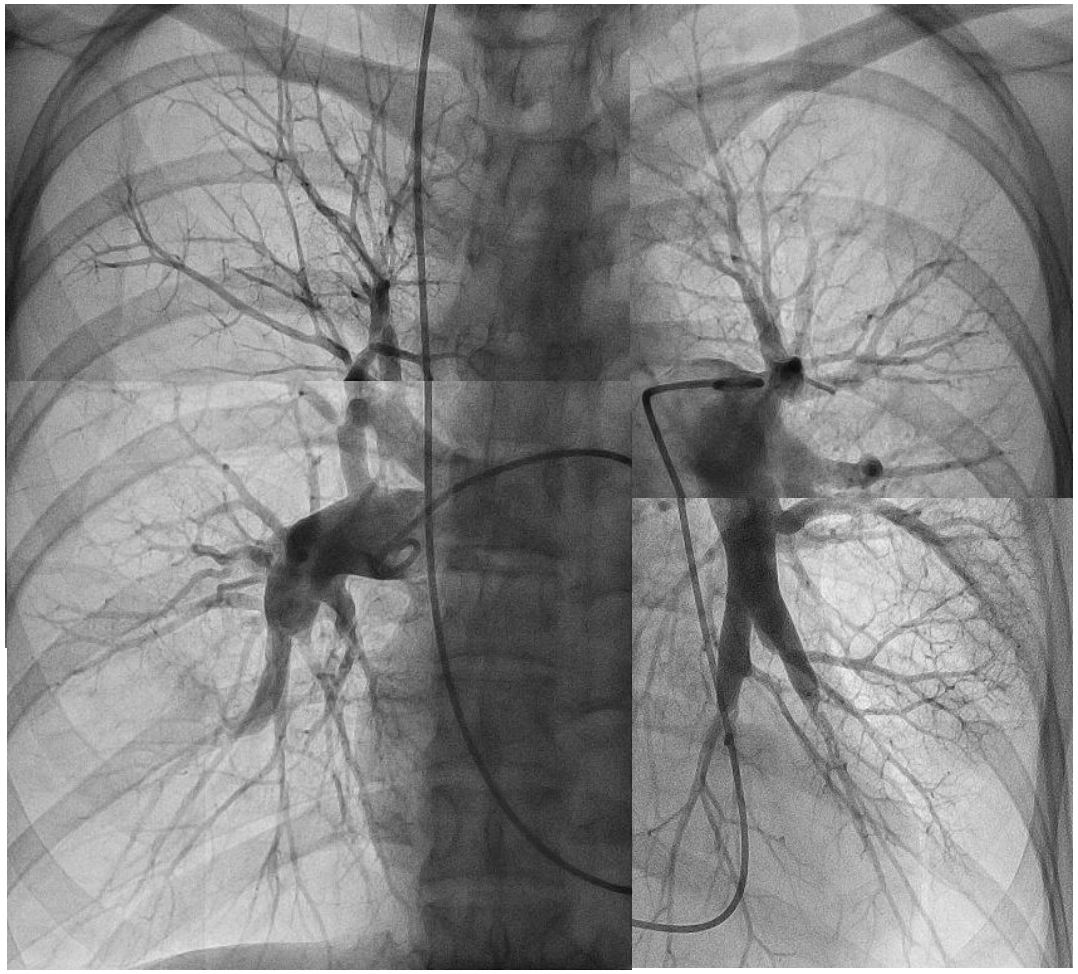
COI Disclosure

Consultation fees: Janssen Pharmaceutical K.K., MSD K.K., Mochida Pharmaceutical Co. Ltd.

remuneration for lecture: Janssen Pharmaceutical K.K., MSD K.K., Nippon Shinyaku Co. Ltd., Bayer Yakuhin Ltd., Mochida Pharmaceutical Co. Ltd., Kaneka Medix Corporation, Nipro, AOP Orphan

scholarship fund: Nippon Shinyaku Co. Ltd.

Chronic Thromboembolic Pulmonary Hypertension (CTEPH)



・CTEPH is rare complication of acute pulmonary embolism.

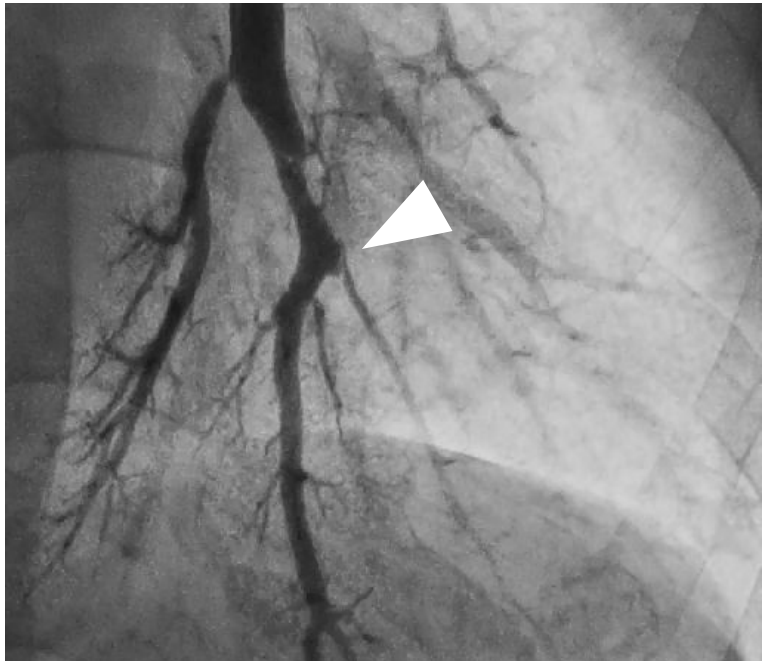
・ Organized thrombi cause stenoses or obstructions of pulmonary arteries.

Okayama Medical Center data.

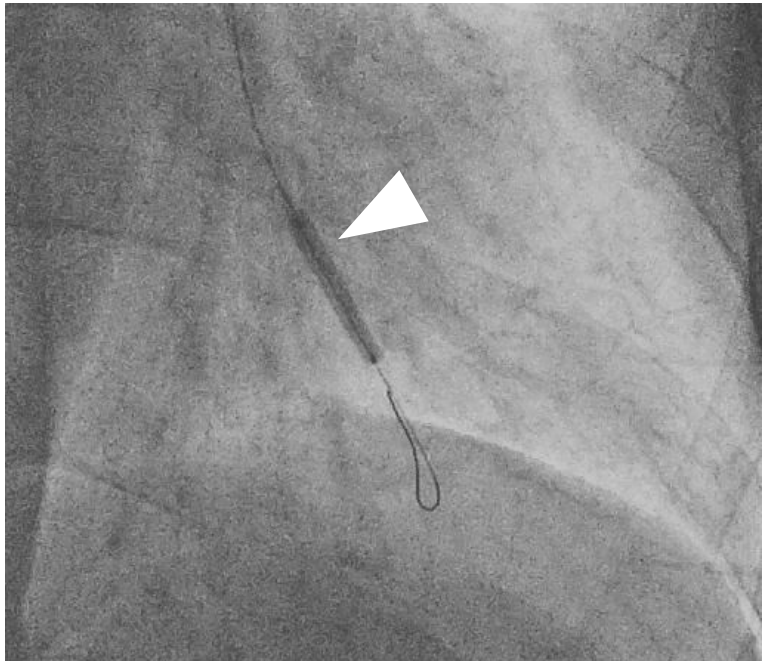
Representative BPA procedure

BPA is Interventional treatment for CTEPH using balloon catheters developed as an alternative treatment for inoperable CTEPH patients.

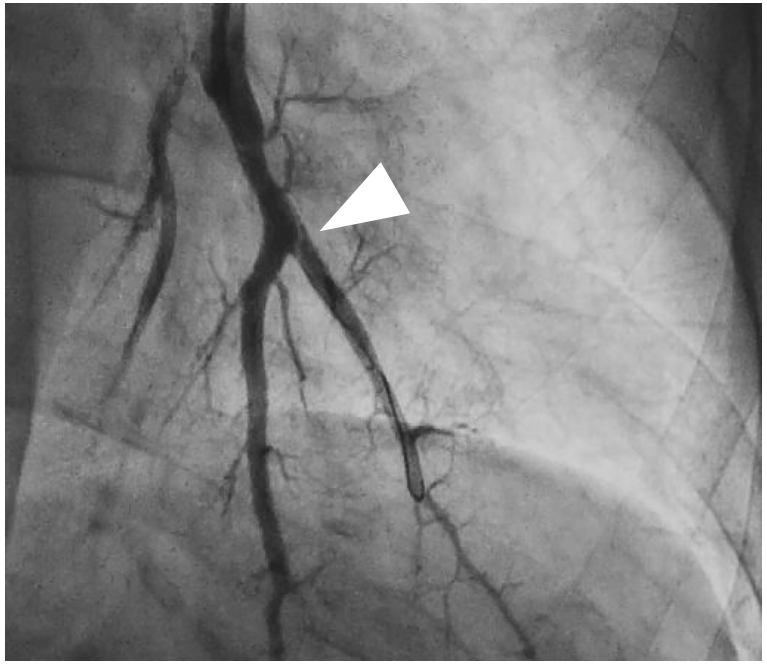
Before BPA



Balloon dilation



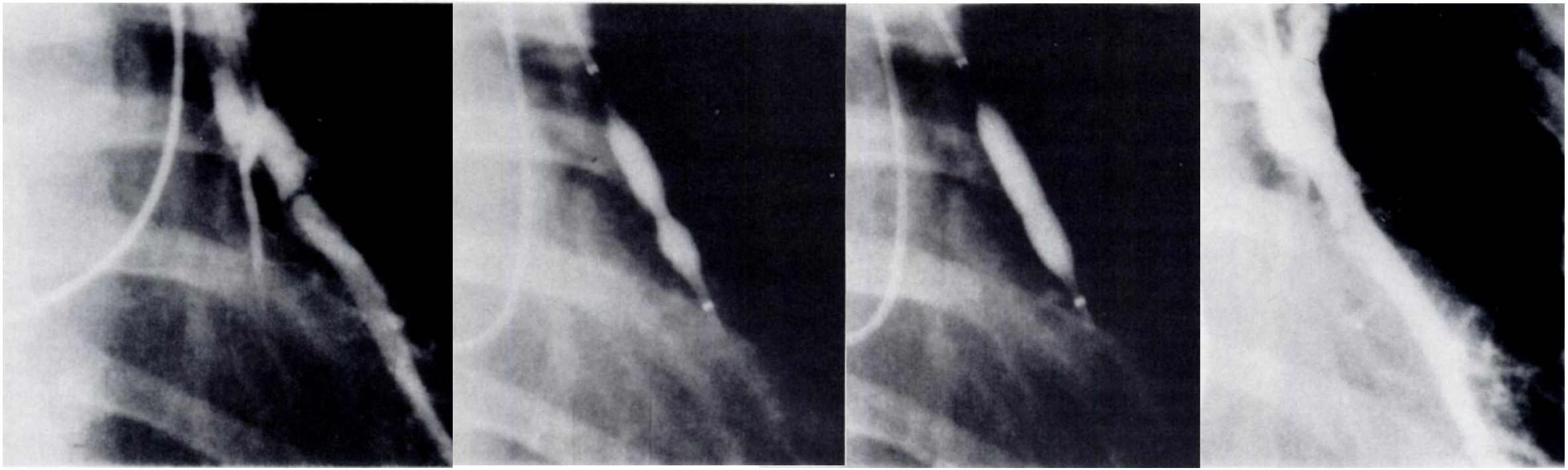
Immediately after BPA



Okayama Medical Center data.

Balloon Angioplasty in the Treatment of Pulmonary Hypertension Caused by Pulmonary Embolism*

Jan A. I. Voorburg, M.D.; Volkert Manger Cats, M.D.; Beert Buis, M.D.; and Albert V. G. Bruschke, M.D., F.C.C.P.



CHEST 1988 Dec;94(6):1249-53.

Brief Rapid Communications

Balloon Pulmonary Angioplasty for Treatment of Chronic Thromboembolic Pulmonary Hypertension

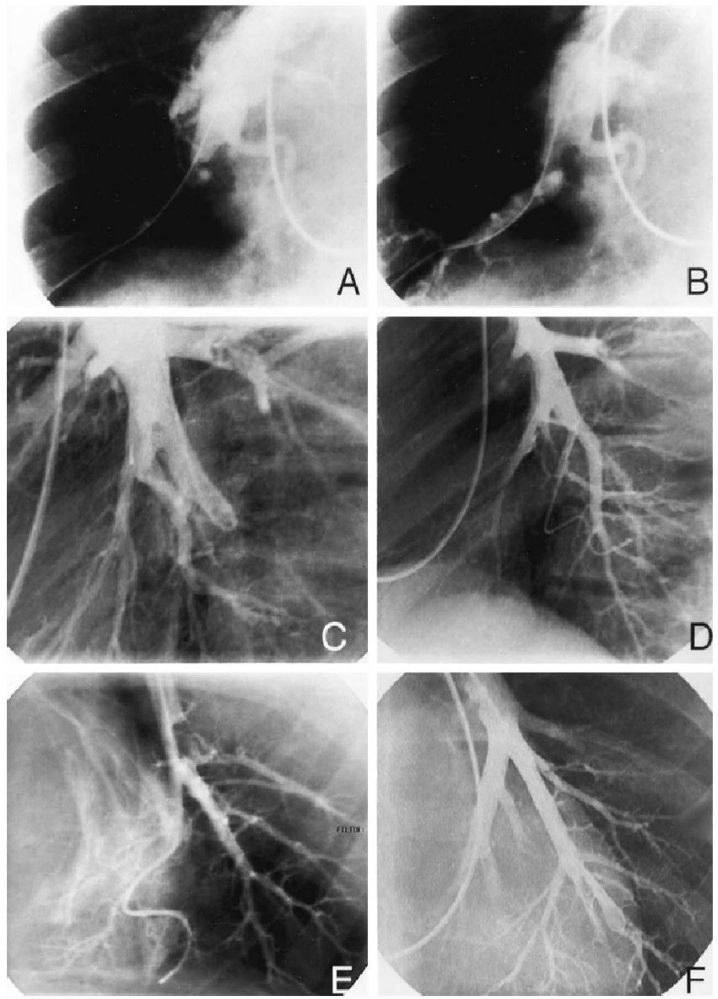
Jeffrey A. Feinstein, MD, MPH; Samuel Z. Goldhaber, MD; James E. Lock, MD; Susan M. Ferndandes, PA-C; Michael J. Landzberg, MD

Background—Although pulmonary thromboendarterectomy is increasingly successful for the definitive treatment of chronic thromboembolic pulmonary hypertension (CTEPH), not all patients have surgically accessible disease. Others are poor surgical candidates because of comorbid illness. Therefore, for selected patients, we defined and implemented an alternative interventional strategy of balloon pulmonary angioplasty (BPA).

Methods and Results—Eighteen patients (mean age, 51.8 years; range, 14 to 75 years) with CTEPH underwent BPA; they averaged 2.6 procedures (range, 1 to 5) and 6 dilations (range, 1 to 12). Selection of pulmonary artery segments for dilation required (1) complete occlusion, (2) filling defects, or (3) signs of intravascular webs. After an average of 36 months of follow-up (range, 0.5 to 66 months), the average New York Heart Association class improved from 3.3 to 1.8 ($P<0.001$), and 6-minute walking distances increased from 209 to 497 yards ($P<0.0001$). Pulmonary artery mean pressures decreased from 43.0 ± 12.1 to 33.7 ± 10.2 mm Hg ($P=0.007$). Eleven patients developed reperfusion pulmonary edema; 3 required mechanical ventilation.

Conclusions—BPA reduces pulmonary artery hypertension in patients with CTEPH and is associated with long-term improvement in New York Heart Association class and 6-minute walking distances. BPA is a promising interventional technique that warrants randomized comparison with medical therapy in CTEPH patients who are not surgical candidates. (*Circulation*. 2001;103:10-13.)

Key Words: balloon ■ angioplasty ■ embolism ■ thrombus ■ pulmonary heart disease



- Averaged 2.6 procedures, 6 dilations
- mPAP decreased from 43.0 to 33.7 mmHg
- About 60 % of patients developed reperfusion edema (one patient died)

Pulmonary Vascular Disease

Refined Balloon Pulmonary Angioplasty for Inoperable Patients with Chronic Thromboembolic Pulmonary Hypertension

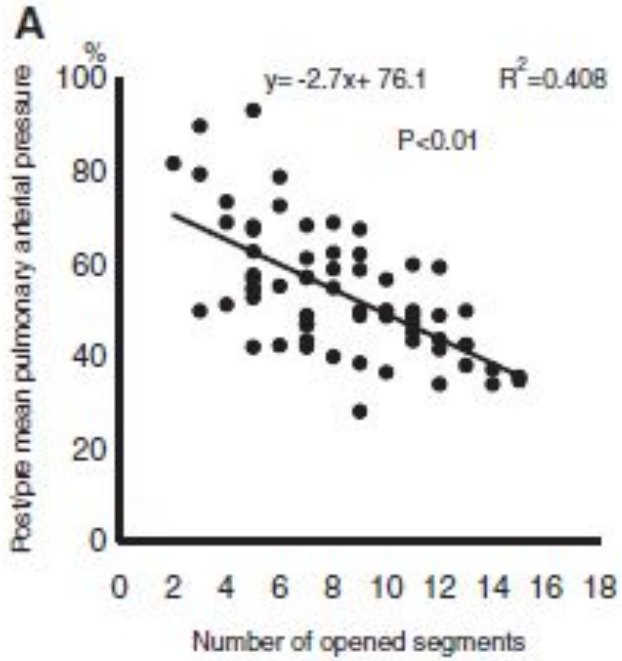
Hiroki Mizoguchi, MD; Aiko Ogawa, MD, PhD; Mitsuru Munemasa, MD, PhD; Hiroshi Mikouchi, MD, PhD; Hiroshi Ito, MD, PhD; Hiromi Matsubara, MD, PhD

Background—Although balloon pulmonary angioplasty (BPA) for inoperable patients with chronic thromboembolic pulmonary hypertension was first reported over a decade ago, its clinical application has been restricted because of limited efficacy and complications. We have refined the procedure of BPA to maximize its clinical efficacy.

Methods and Results—Sixty-eight consecutive patients with inoperable chronic thromboembolic pulmonary hypertension underwent BPA. We evaluated pulmonary artery diameters and determined the appropriate balloon size by using intravascular ultrasound. We performed BPA in a staged fashion over multiple, separate procedures to maximize efficacy and reduce the risk of reperfusion pulmonary injury. A total of 4 (2–8) sessions were performed in each patient, and the number of vessels dilated per session was 3 (1–14). The World Health Organization functional class improved from 3 to 2 ($P<0.01$), and mean pulmonary arterial pressure was decreased from 45.4±9.6 to 24.0±6.4 mm Hg ($P<0.01$). One patient died because of right heart failure 28 days after BPA. During follow-up for 2.2±1.4 years after the final BPA, another patient died of pneumonia, and the remaining 66 patients are alive. In 57 patients who underwent right heart catheterization at follow-up, improvement of mean pulmonary arterial pressure was maintained (24.0±5.8 mm Hg at 1.0±0.9 years). Forty-one patients (60%) developed reperfusion pulmonary injury after BPA, but mechanical ventilation was required in only 4 patients.

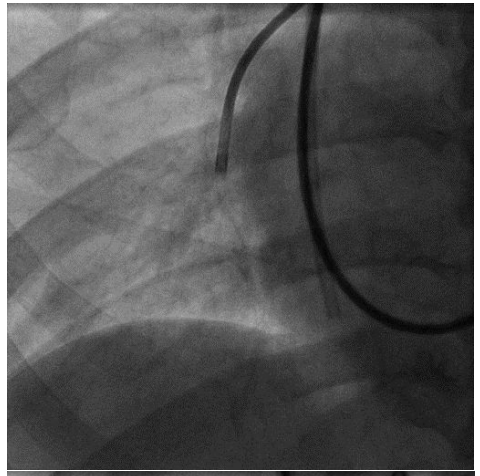
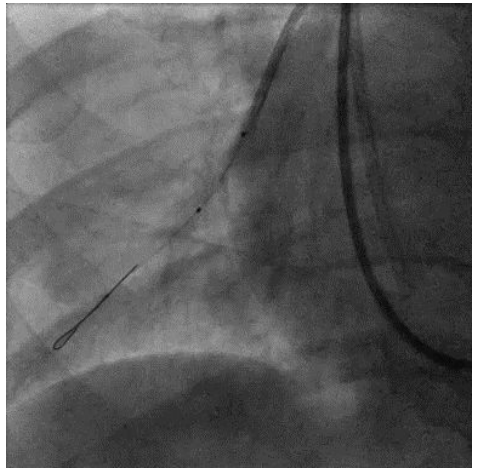
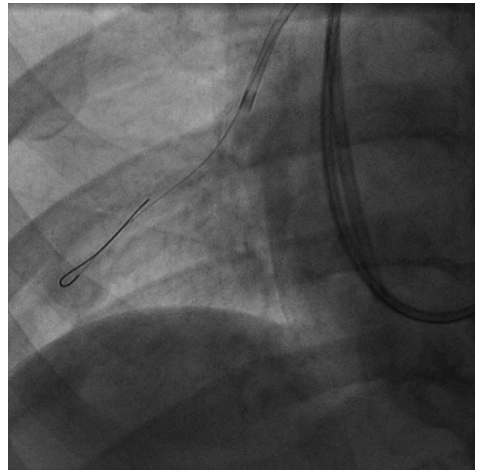
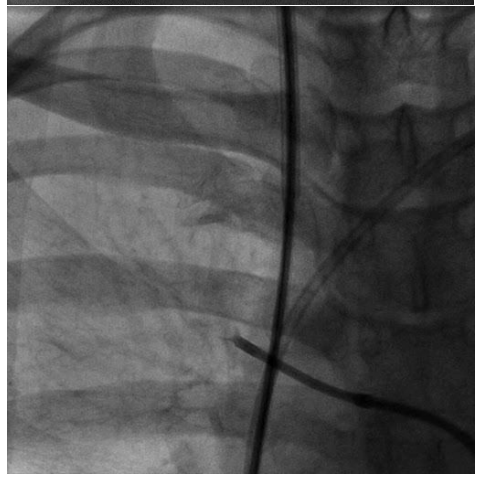
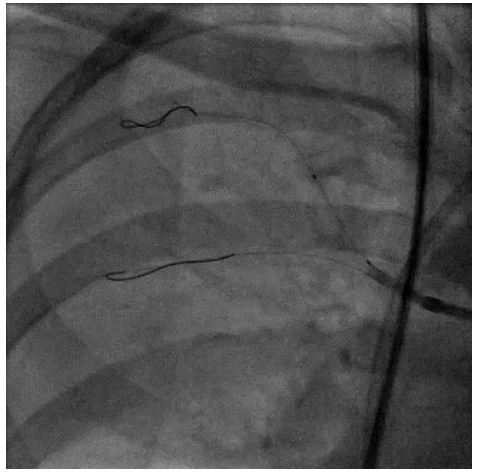
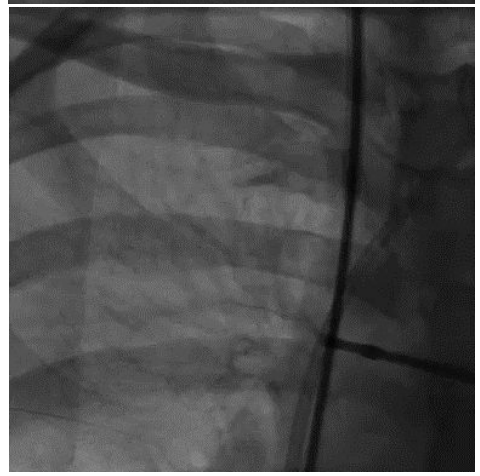
Conclusions—Our refined BPA procedure improves clinical status and hemodynamics of inoperable patients with chronic thromboembolic pulmonary hypertension, with a low mortality. A refined BPA procedure could be considered as a therapeutic approach for patients with inoperable chronic thromboembolic pulmonary hypertension. (***Circ Cardiovasc Interv.* 2012;5:748-755.**)

Key Words: peripheral vascular disease ■ pulmonary hypertension ■ reperfusion ■ revascularization



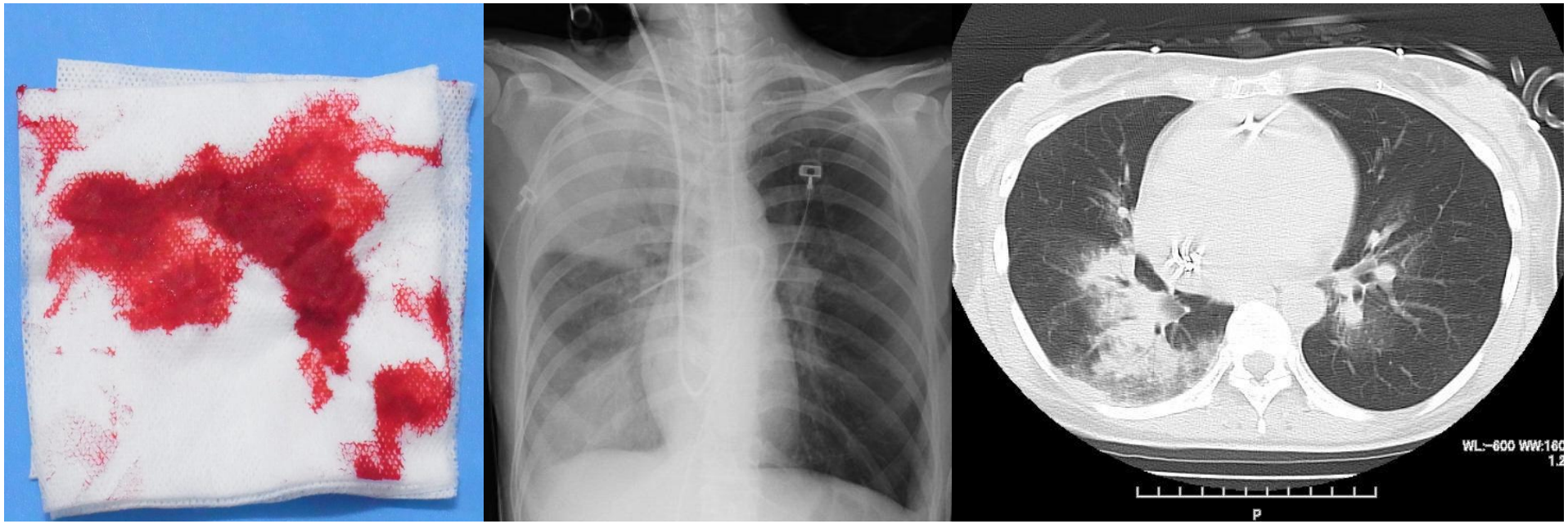
- Averaged 4 procedures, 12 dilations
- mPAP decreased from 45.4 to 24.0 mmHg
- 60 % of patients developed lung injury (one patient died)

Representative BPA procedure before 2012

	Before BPA	During BPA	After BPA
Rt A8			
Rt A3			

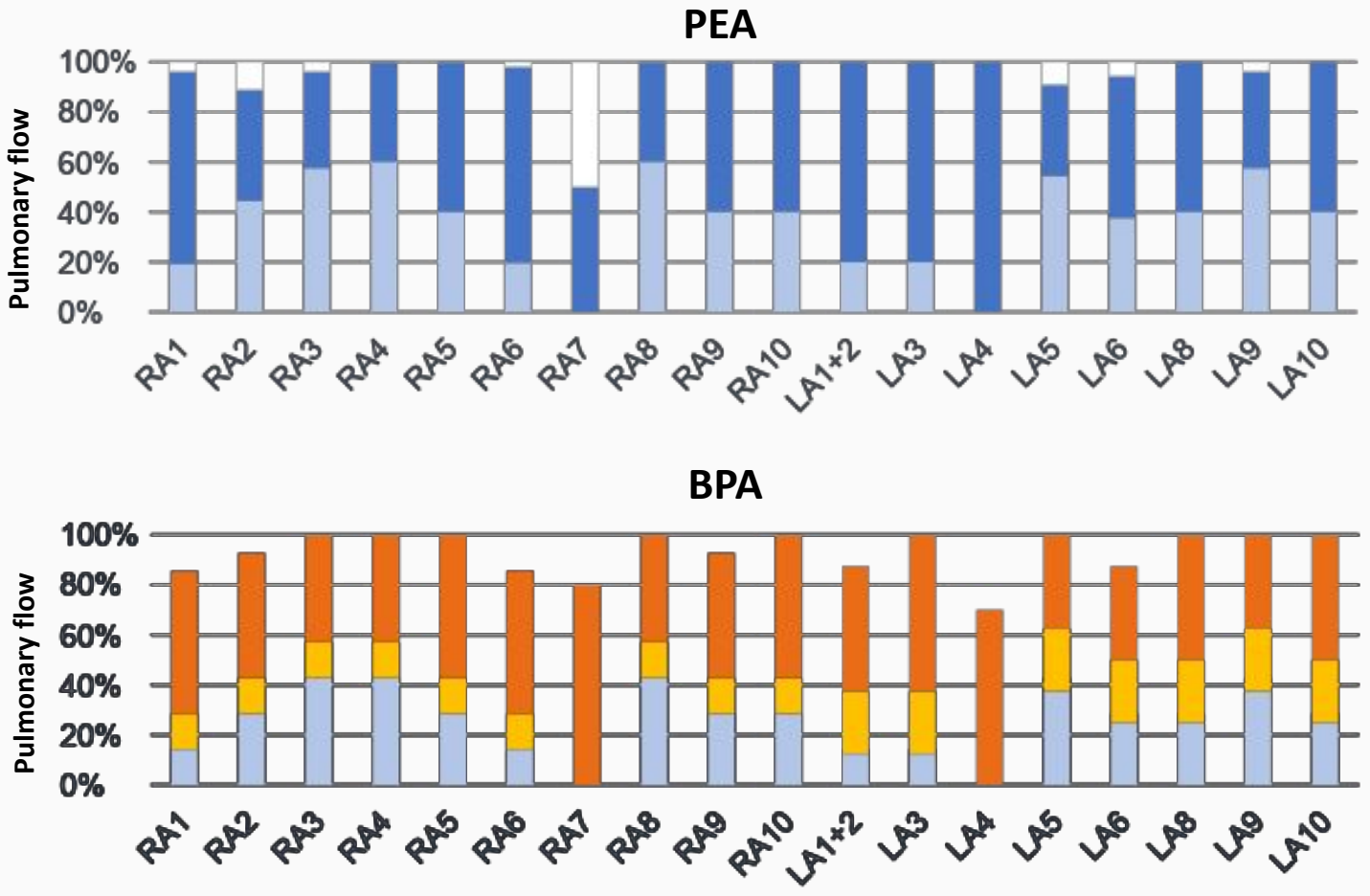
Okayama Medical Center data

Aiming for complete dilation of the lesion may cause pulmonary injury due to hemorrhage from vascular injury



Okayama Medical Center data

Current BPA strategy – staged dilatations

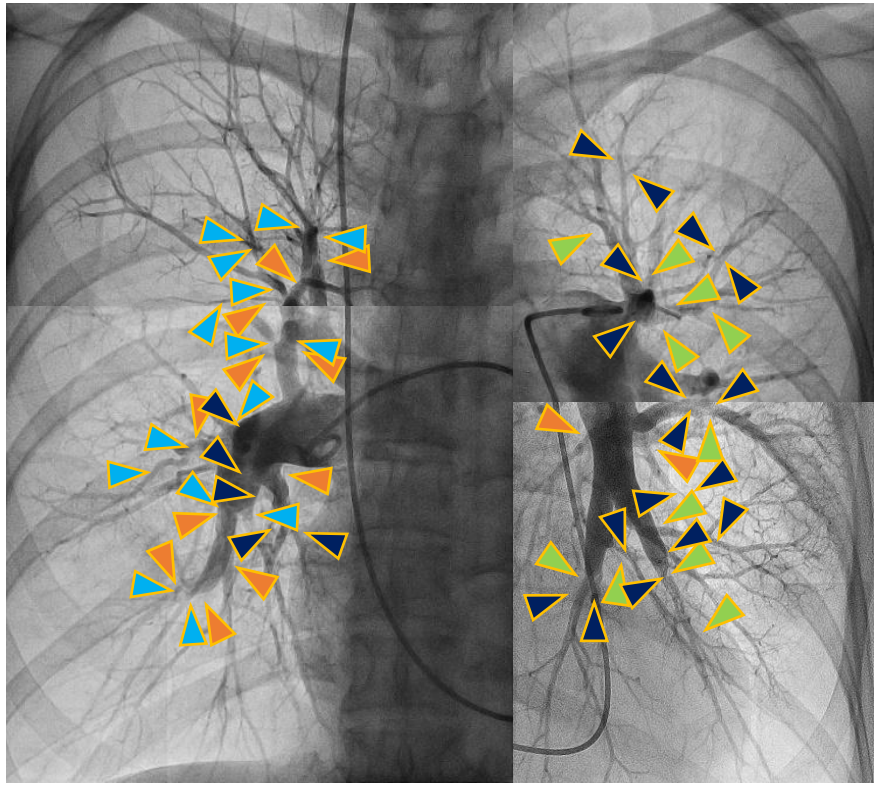


Median of BPA session number to complete the treatment in a patient is 4.

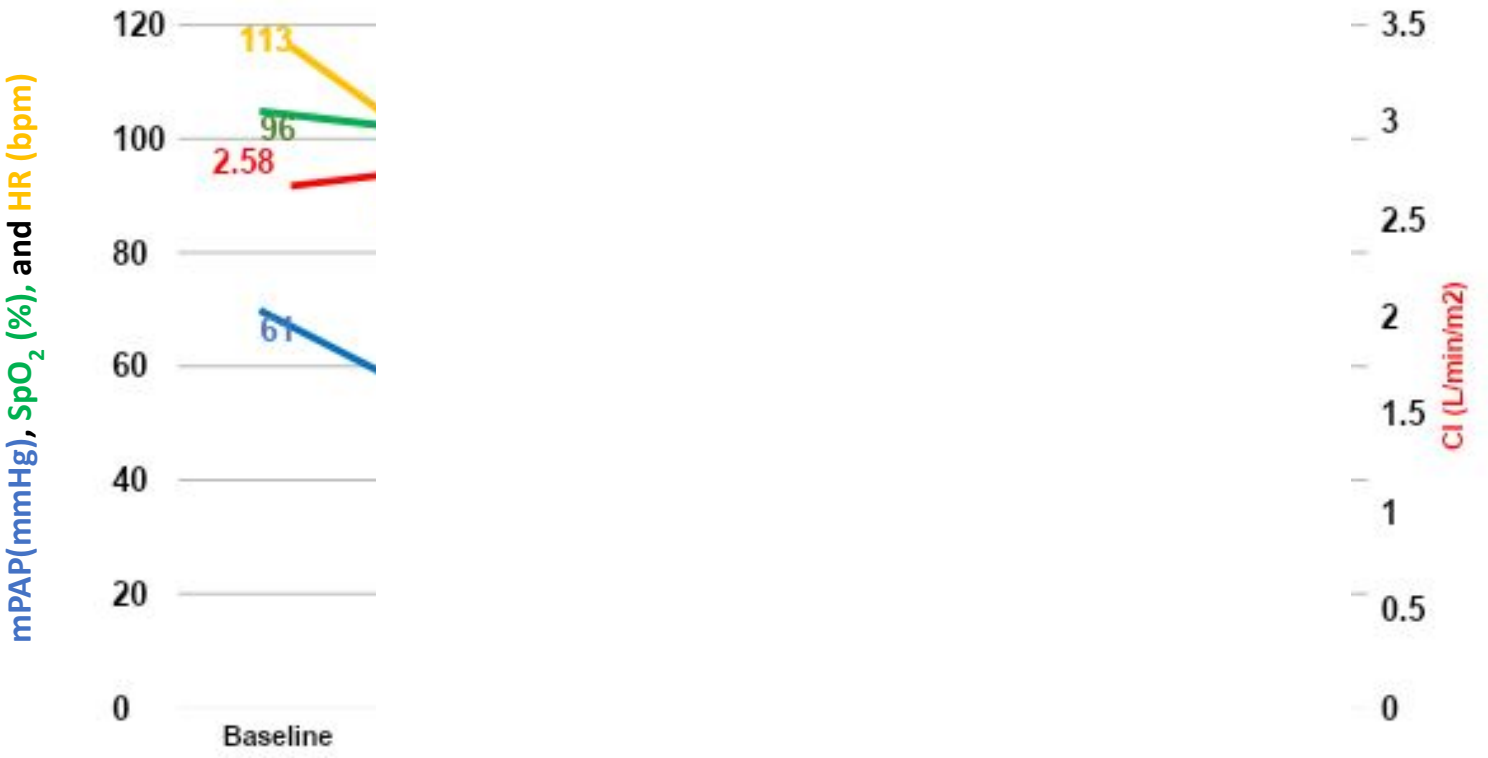
LA, left pulmonary artery; RA, right pulmonary artery.

Current BPA

30 y.o. female



BPA 1
BPA 2
BPA 3
BPA 4



Okayama Medical Center data.

Pulmonary angiogram before and after the current BPA

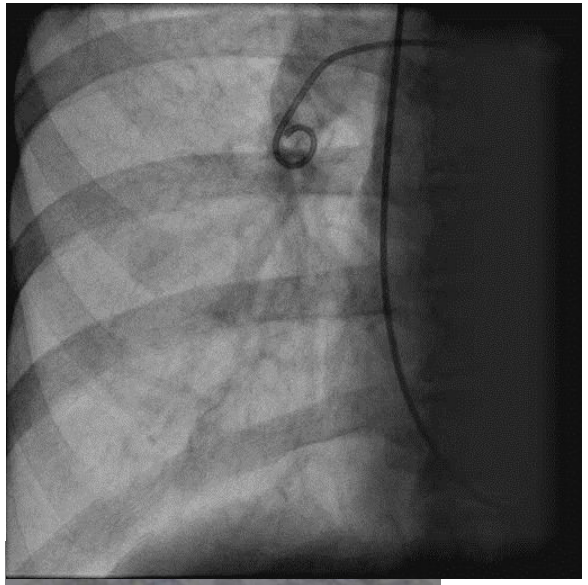
Before BPA

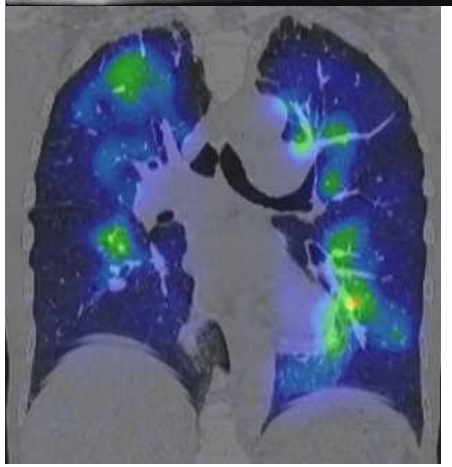
6 months after 4 BPA procedures

Okayama Medical Center data.

Representative Pulmonary angiography of inoperable CTEPH case (50s years, female)

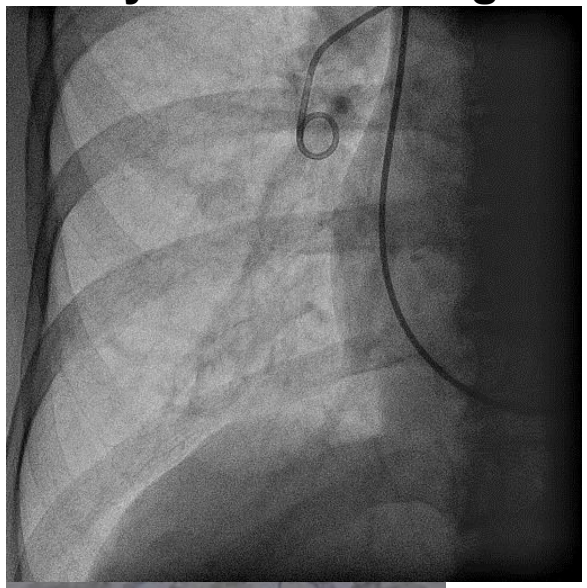
Baseline

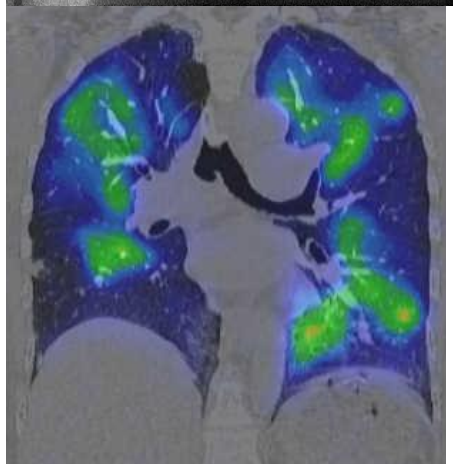




mPAP 41mmHg
PVR 9.2WU
6MWD 350m
SpO2 91%

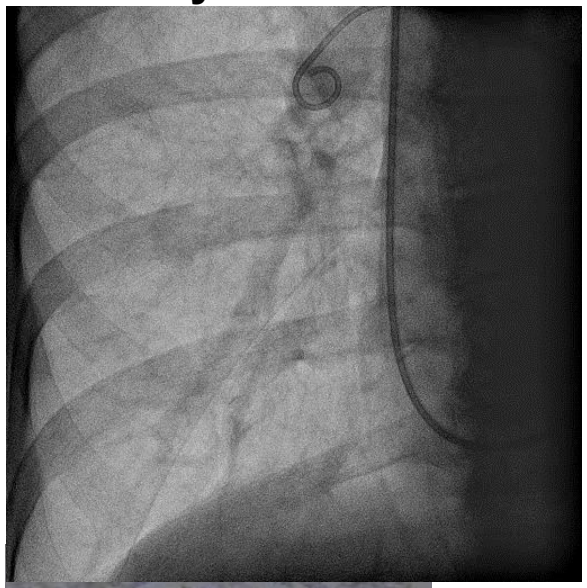
One year after Riociguat

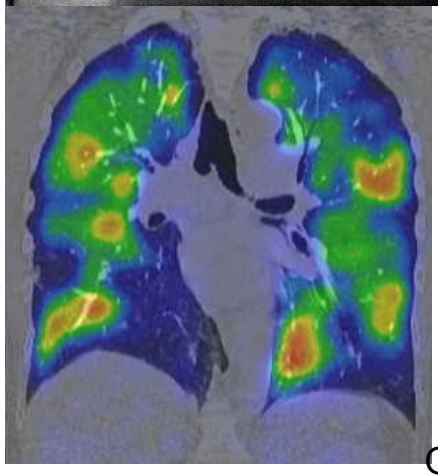




mPAP 36mmHg
PVR 5.2WU
6MWD 400m
SpO2 90%

One year after BPA





mPAP 21mmHg
PVR 2.7WU
6MWD 435m
SpO2 97%

Okayama Medical Center data.

Initial experience of BPA in Japan

Original Article

Balloon Pulmonary Angioplasty for Chronic Thromboembolic Pulmonary Hypertension

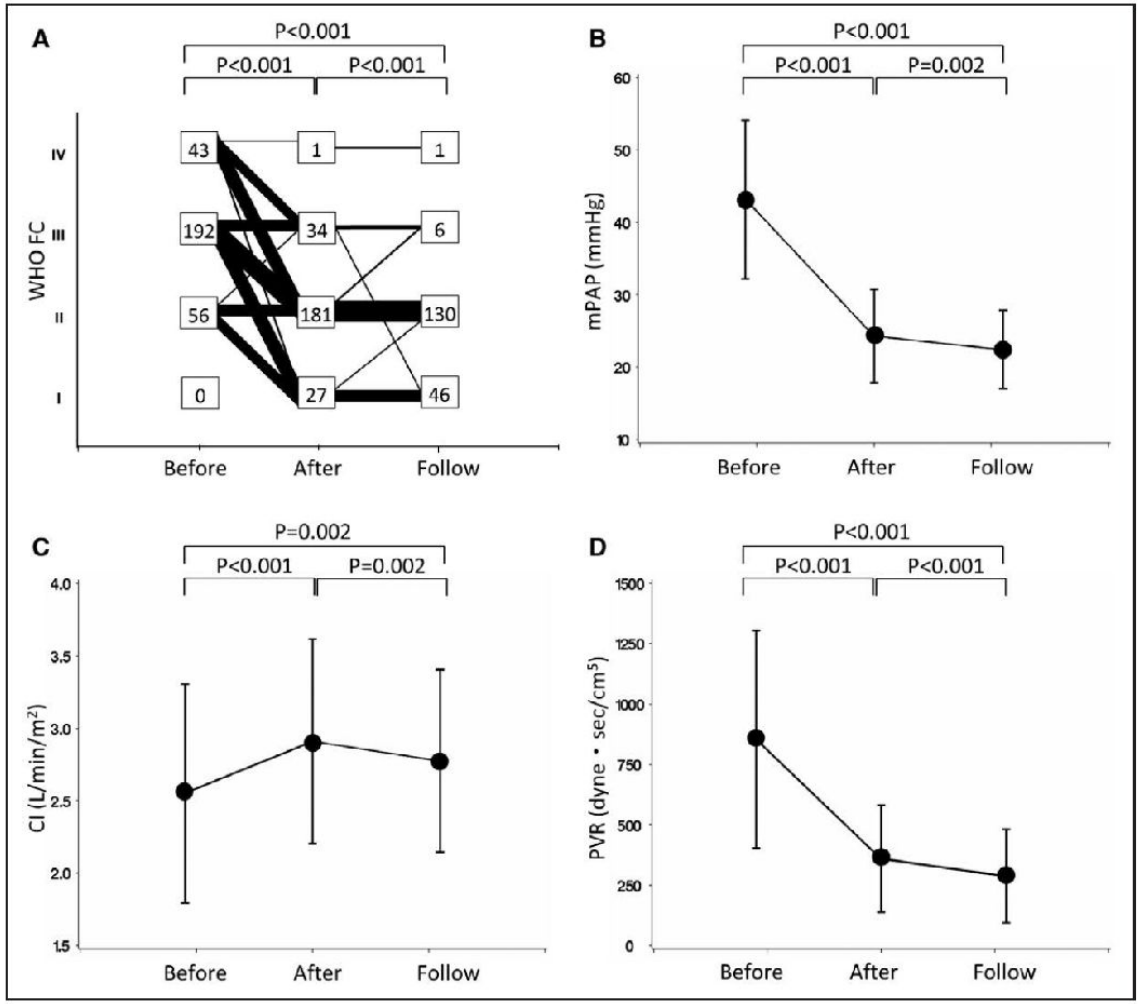
Results of a Multicenter Registry

Aiko Ogawa, MD, PhD; Toru Satoh, MD, PhD; Tetsuya Fukuda, MD, PhD; Koichiro Sugimura, MD, PhD; Yoshihiro Fukumoto, MD, PhD; Noriaki Emoto, MD, PhD; Norikazu Yamada, MD, PhD; Atsushi Yao, MD, PhD; Motomi Ando, MD, PhD; Hitoshi Ogino, MD, PhD; Nobuhiro Tanabe, MD, PhD; Ichizo Tsujino, MD, PhD; Masayuki Hanaoka, MD, PhD; Kenji Minatoya, MD, PhD; Hiroshi Ito, MD, PhD; Hiromi Matsubara, MD, PhD

Background—Balloon pulmonary angioplasty (BPA) is an alternative therapy for patients with chronic thromboembolic pulmonary hypertension who are ineligible for pulmonary endarterectomy—the standard therapy. Currently, most reported results of BPA are from relatively small cohorts treated at single centers. The present study evaluated the safety and efficacy of BPA for chronic thromboembolic pulmonary hypertension based on a multicenter registry.

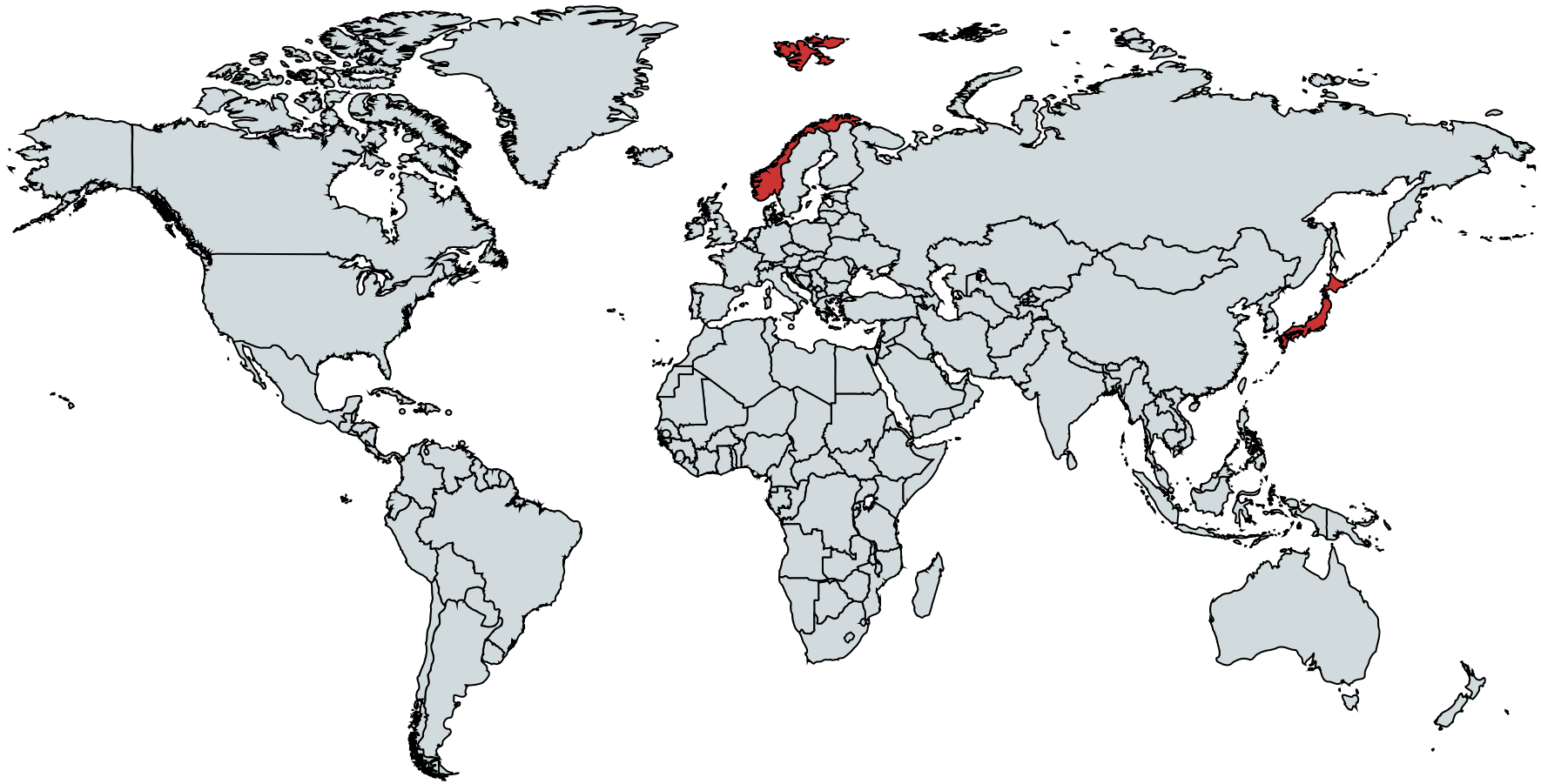
Methods and Results—A total of 308 patients (62 men and 246 women; mean age, 61 years) underwent 1408 procedures at 7 institutions in Japan. Data were retrospectively reviewed to evaluate clinical outcome and complications. Hemodynamics were significantly improved in 249 patients in whom BPA was terminated, most often because of improvement in mean pulmonary arterial pressure or symptomatic improvement after 1154 procedures. In 196 patients who underwent follow-up right heart catheterization, improvement of hemodynamic parameters was maintained. Mean pulmonary arterial pressure decreased from 43.2±11.0 to 24.3±6.4 mm Hg after final BPA and 22.5±5.4 mm Hg at follow-up, with significant reduction of concomitant use of pulmonary hypertension-targeted therapy and oxygen supplementation. Complications occurred in 511 (36.3%), including pulmonary injury (17.8%), hemoptysis (14.0%), and pulmonary artery perforation (2.9%). Twelve patients (3.9%) died during follow-up, including 8 patients who died within 30 days after BPA. The leading causes of death were right heart failure, multiorgan failure, and sepsis. Overall survival was 96.8% (95% confidence interval, 93.7%–98.4%) at 1 and 2 years and 94.5% (95% confidence interval, 89.3%–97.3%) at 3 years, respectively, after the initial BPA procedure for all 308 patients.

Conclusions—This multicenter registry suggested improved hemodynamic results after BPA. Complication rates were high, but overall survival was comparable with pulmonary endarterectomy. BPA may be an important therapeutic option in patients with chronic thromboembolic pulmonary hypertension. (***Circ Cardiovasc Qual Outcomes*. 2017;10:e004029. DOI: 10.1161/CIRCOUTCOMES.117.004029.)**

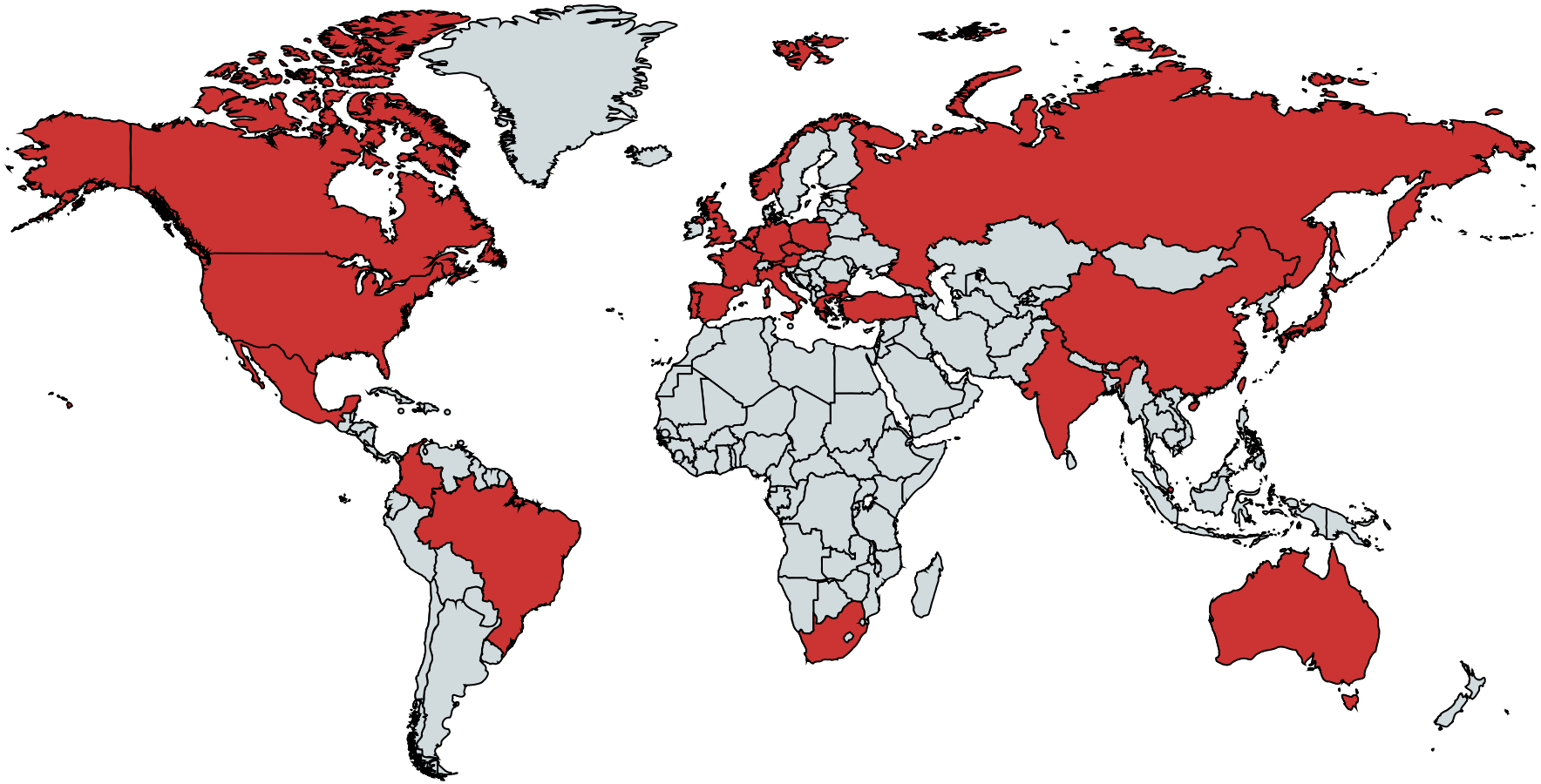


Ogawa A, et al. Circ Cardiovasc Qual Outcomes. 2017 Nov;10(11). pii: e004029. doi: 10.1161/CIRCOUTCOMES.117.004029.

BPA in 2012



BPA in 2022



Outcomes of BPA

country	fFrst author	Year	Patients number	Total # of BPA	f/u (M)	Base line PH med	Lung injury (n (% of sessions))	30-day mortality (%)	3 year survival (%)	mPAP (mmHg)			CO (L/min)			PVR (W.U.)			6MWD (m)		
Multicentre registries																					
										baseline	f/u	Δ%	baseline	f/u	Δ%	baseline	f/u	Δ%	baseline	f/u	Δ%
Japan	Ogawa	2004-2013	308 (249f/u)	1408	14.2 ±9.4	72,0	251 (17.8)	2,6	94,5	43.2 ±11.0	22.5 ±5.4	-47,9	2.60 ±0.80	2.80± 0.60	7,7	10.7± 5.6	3.6± 2.4	-66,4	318±122	430±109	35,1
Poland	Darocha	2013-2019	236 (156f/u)	1056	14-25	69,4	68 (6.4)	1,7	92,4	46.1 ±10.6	32,7 ±10.9	-29,1	2.86 ±0.79	2.94± 0.72	2,8	7.9± 5.5	4.3± 2.2	-45,6	346±135	402±137	16,2
Prospective randomized controlled trials																					
France	Jaïs	2016-2019	52 (52f/u)	400	6	0,0	8 (2.0)	0	NA	46.5 ±8.4	27,8	-40,2	4.20 ±0.90	4,90	16,7	9.6± 3.1	3.9± 1.6	-59,8	380±103	430	13,2
Japan	Kawakami	2016-2019	31 (31f/u)	147	12	0,0	1 (0.7)	0	NA	38.1 ±7.9	21.4 ±4.7	-43,8	4.29 ±1.31	4.44± 0.90	3,5	8.1± 3.3	3.3± 0.8	-59,3	364±105	427±117	17,3

Lang IM, et al.Eur Heart J. 2023 Aug 1;44(29):2659-2671. doi: 10.1093/eurheartj/ehad413.

Summary

- BPA was born in 1988 and grow up in Japan.
- The safety and the efficacy of BPA has been established.
- BPA is accepted globally as a treatment option for inoperable CTEPH.