Angioplasty for Chronic Total Occlusion (CTO)

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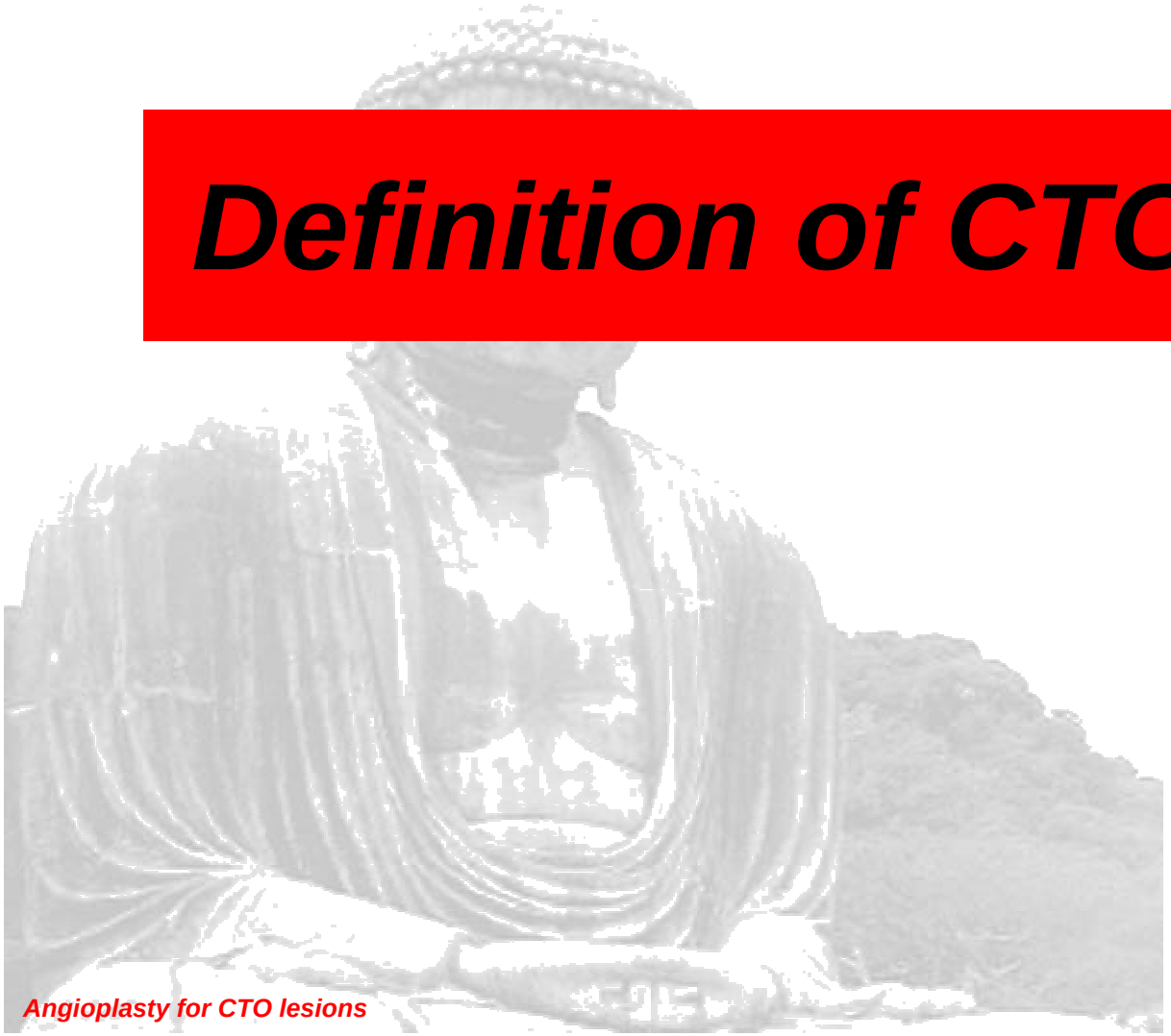
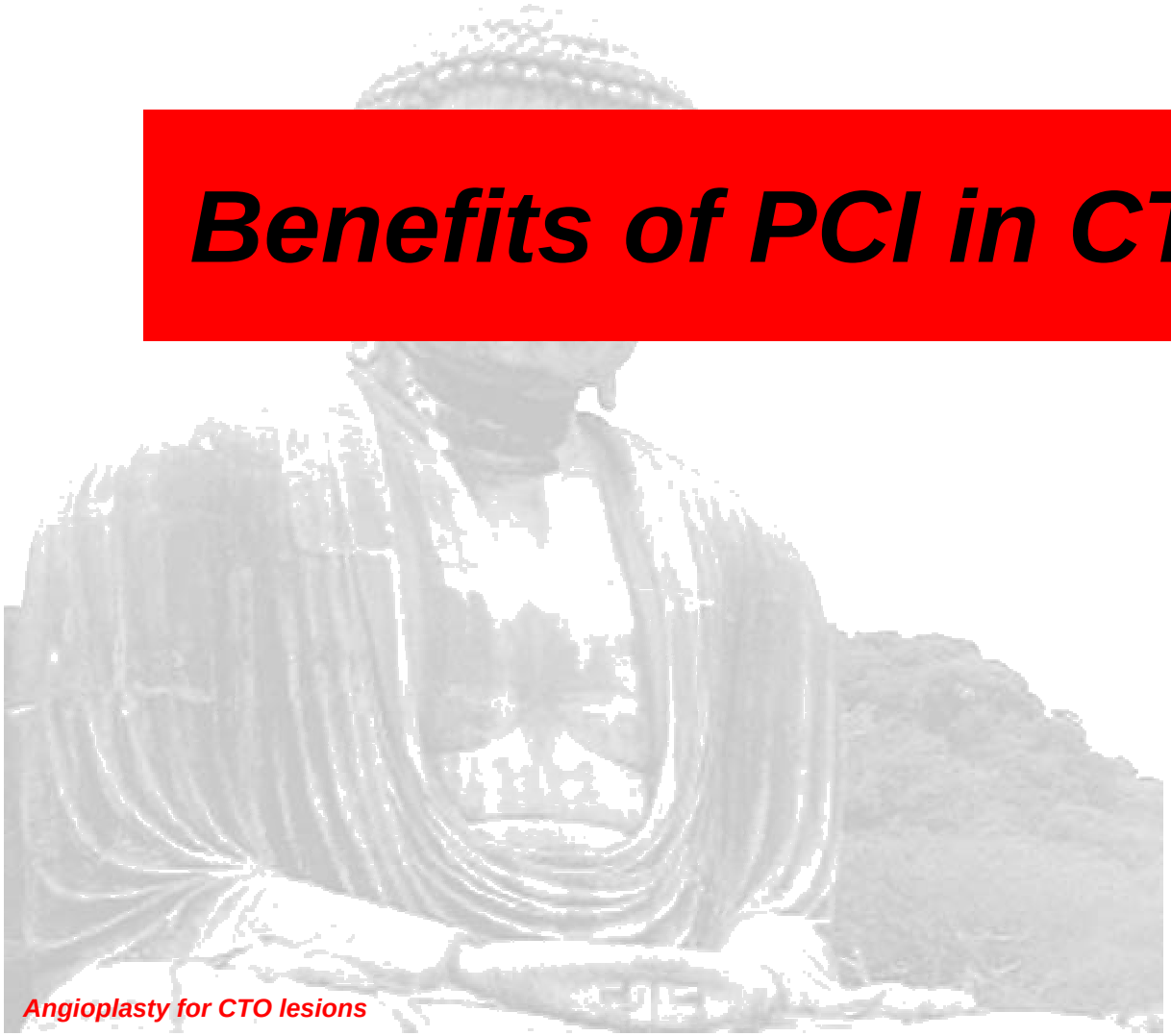
Definition of CTO lesions



Definition of CTO lesions

- **Total occlusion:**
  - 100% luminal diameter stenosis
  - No anterograde blood flow
  - TIMI grade 0
- **Duration of occlusion:**
  - >= 3 months
  - Should be calculated on the basis of clinical or angiographic data, or both

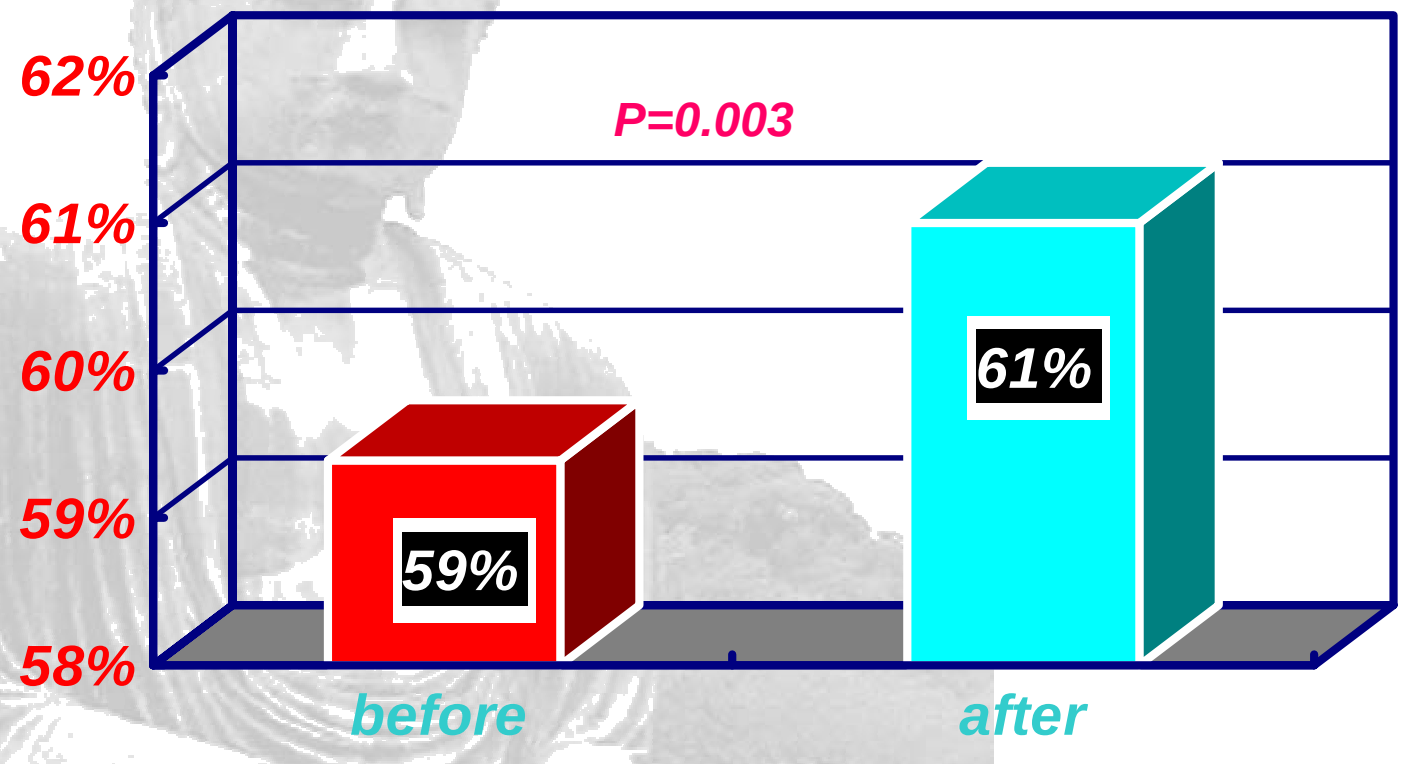
Benefits of PCI in CTO lesions



Restoration of blood flow in CTO lesions can improve LV function

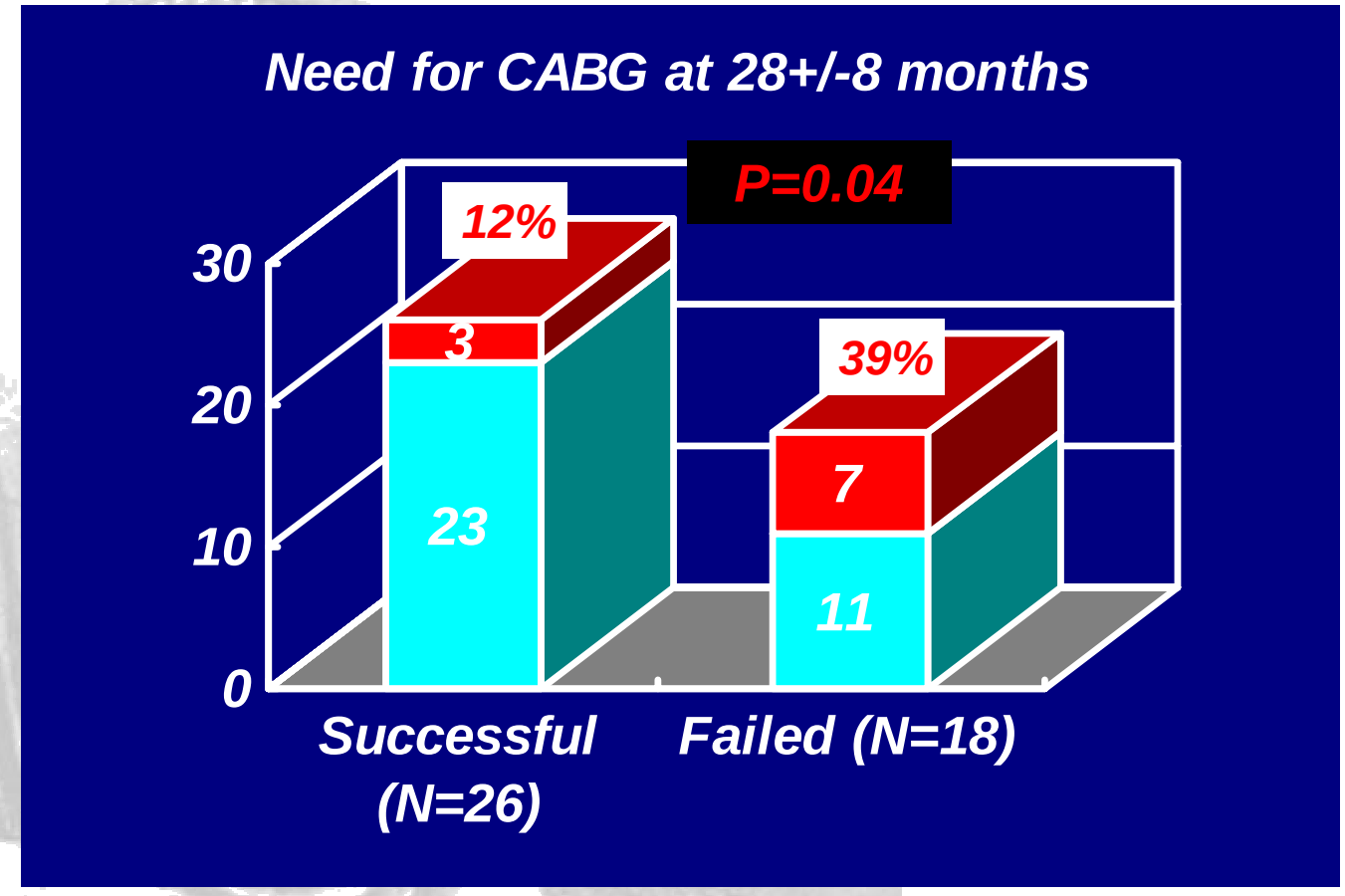
Dzavik V, et al. Predictors of improvement in left ventricular function after percutaneous revascularization of occluded coronary arteries: a report from the Total Occlusion Study of Canada (TOSCA). Am Heart J 2001; 142: 301-8.

Global LVEF before and after the opening of CTO lesions



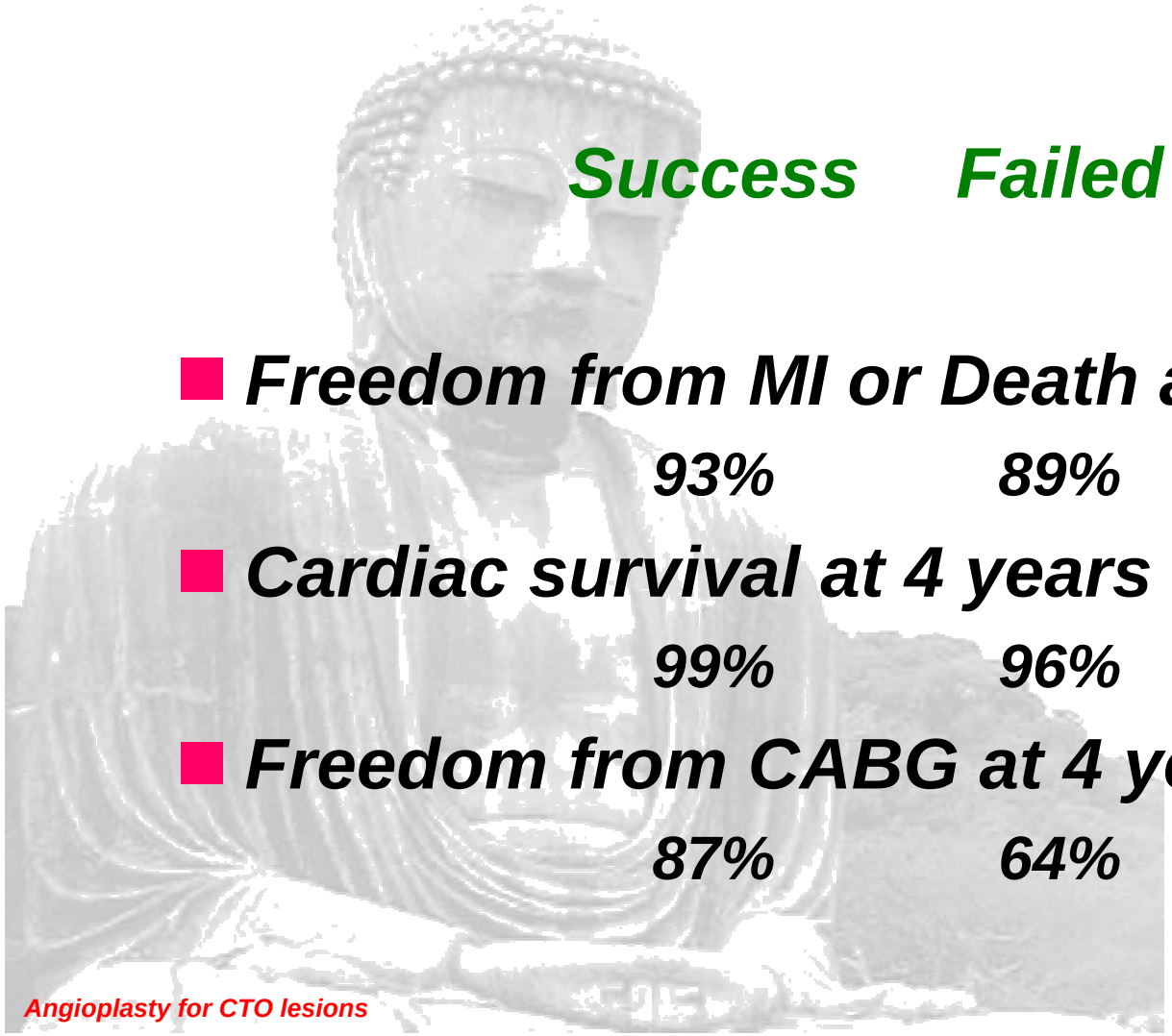
Coronary angioplasty for CTO lesions reduces the need for subsequent CABG

Warren RJ, et al. Coronary angioplasty for chronic total occlusion reduces the need for subsequent coronary bypass surgery. Am Heart J 1990; 120: 270-4.



Long-term survival after PCI success or failure in CTO lesions

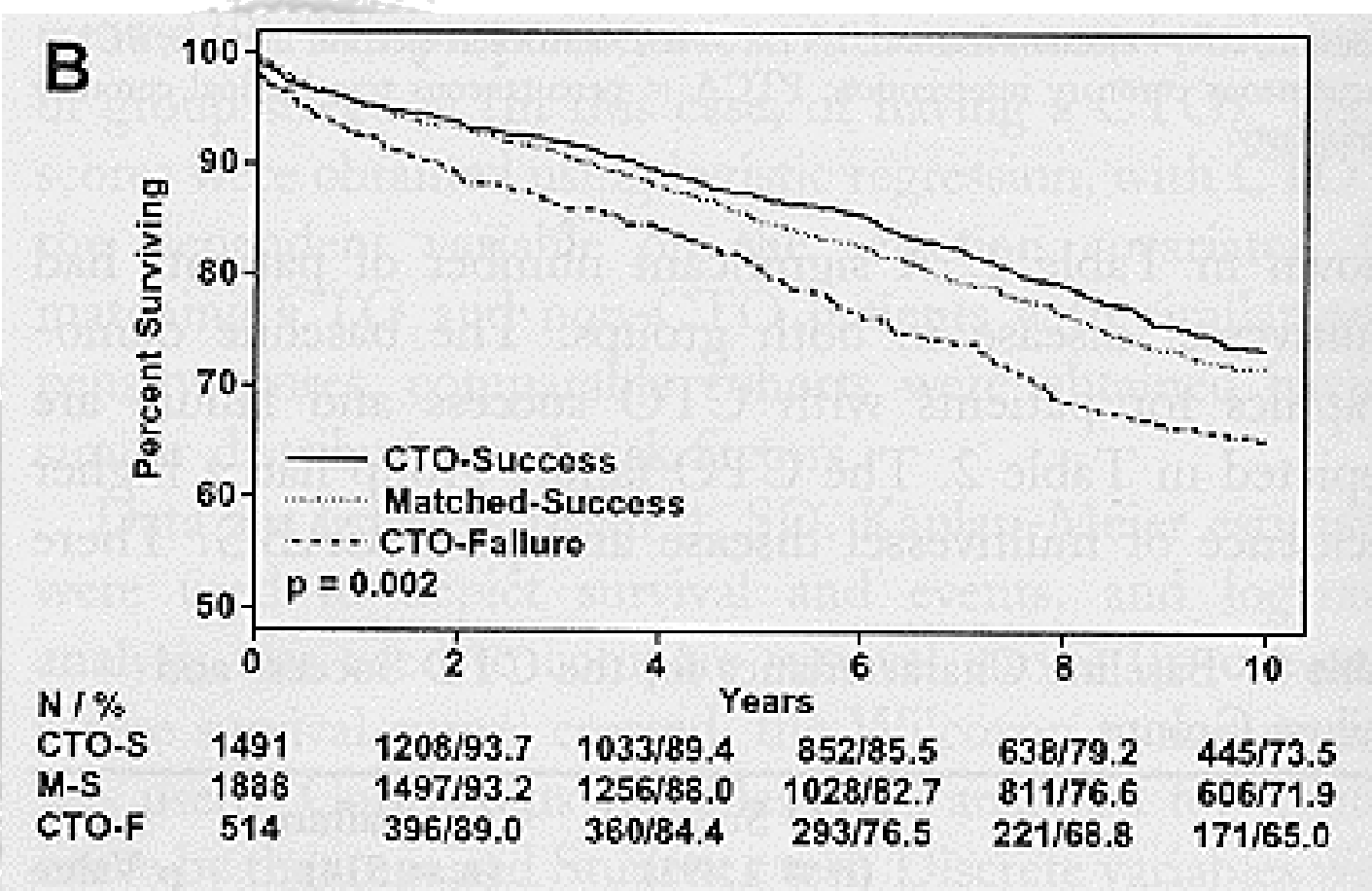
Ivanhoe RJ, et al. Percutaneous transluminal coronary angioplasty of chronic total occlusions. Circulation 1992; 85: 106-115.



	Success	Failed	p
Freedom from MI or Death at 4 year	93%	89%	0.0044
Cardiac survival at 4 years	99%	96%	0.006
Freedom from CABG at 4 years	87%	64%	<0.0001

Survival after Successful PCI for CTO

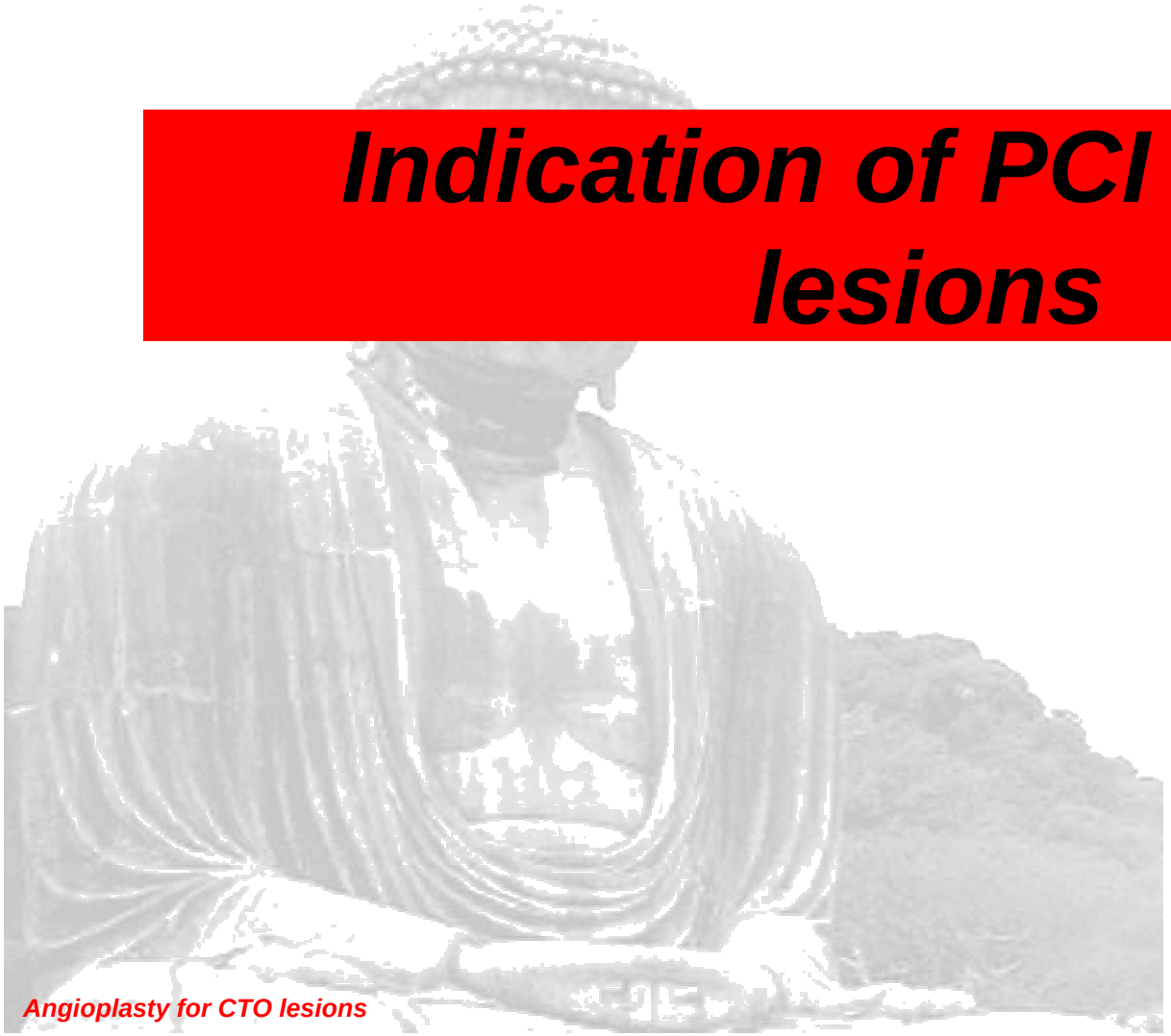
Suero JA, et al. Procedural outcomes and long-term survival among patients undergoing percutaneous coronary intervention of a chronic total occlusion in native coronary arteries: a 20-year experience. J Am Coll Cardiol 2001; 38: 409-14.



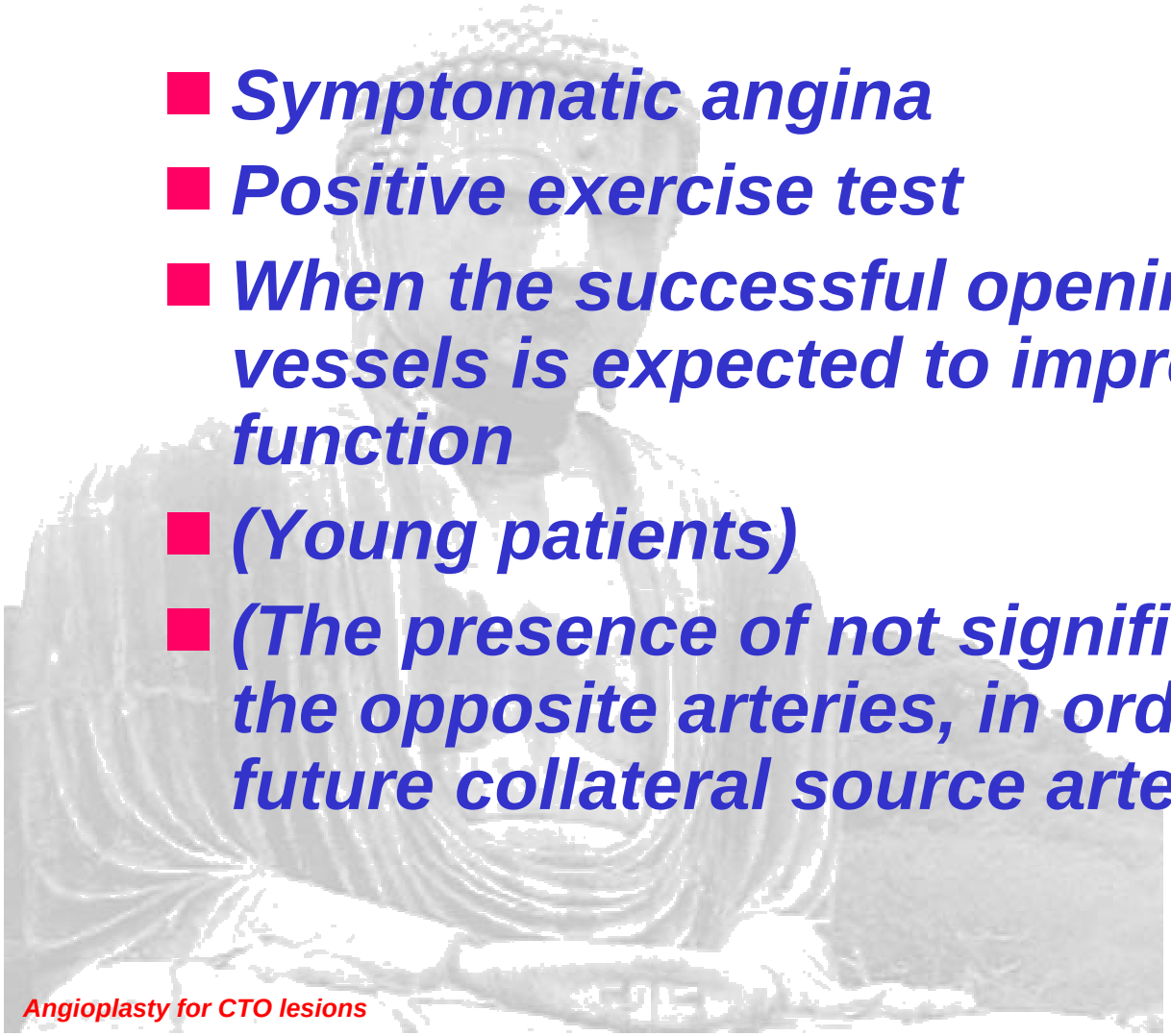
N / %						
CTO-S	1491	1206/93.7	1033/89.4	852/85.5	638/79.2	445/73.5
M-S	1888	1497/93.2	1256/88.0	1028/82.7	811/76.6	606/71.9
CTO-F	514	396/89.0	360/84.4	293/76.5	221/68.8	171/65.0

Successful opening of CTO lesions by PCI can improve the long-term outcomes of the patients.

Indication of PCI in CTO lesions



Indications for PCI in CTO lesions

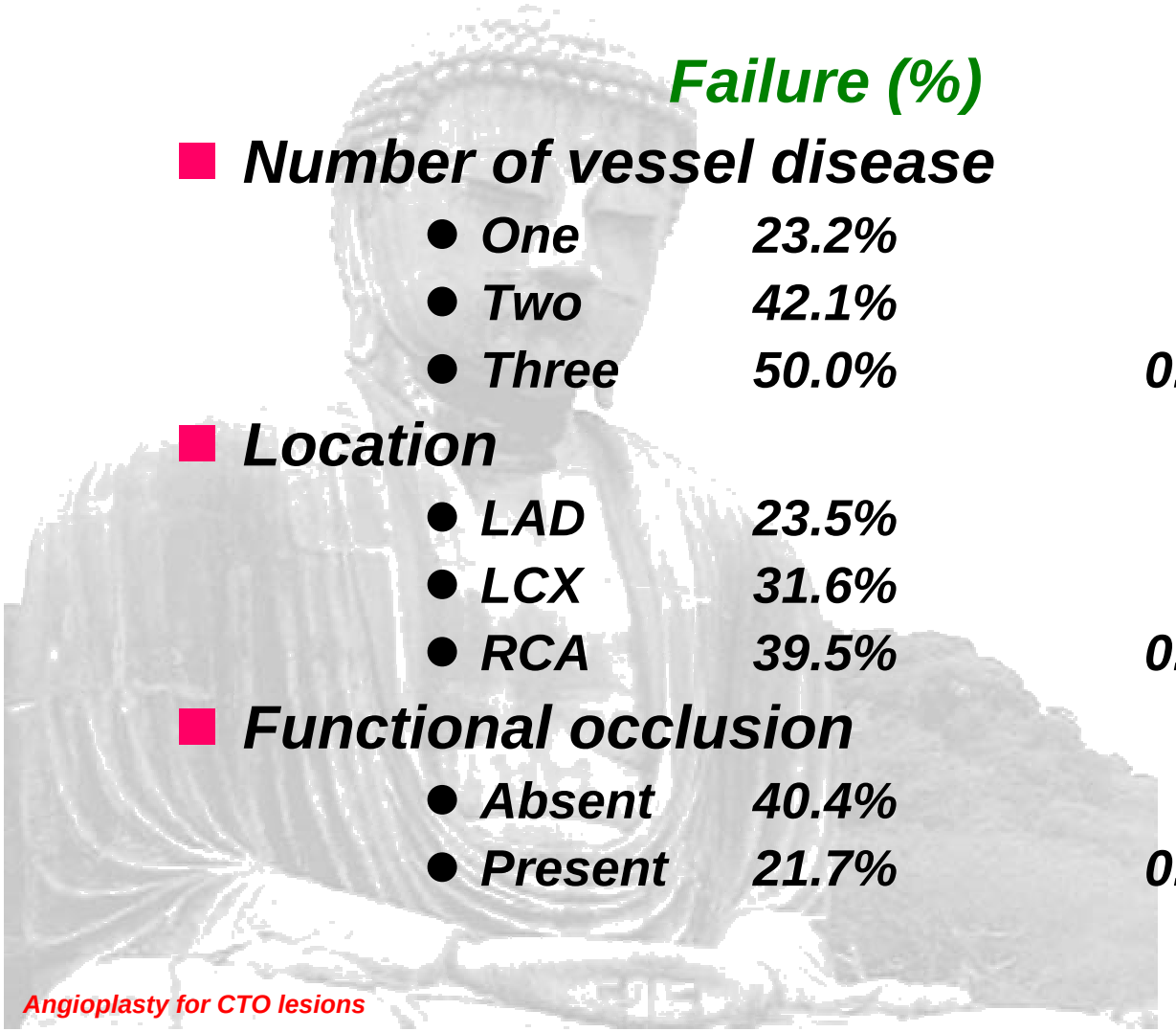


- *Symptomatic angina*
- *Positive exercise test*
- *When the successful opening of the vessels is expected to improve LV function*
- *(Young patients)*
- *(The presence of not significant lesion in the opposite arteries, in order to ensure a future collateral source artery)*

What are the predictors for PCI success in CTO lesions?

Predictors of procedural failure in CTO lesions

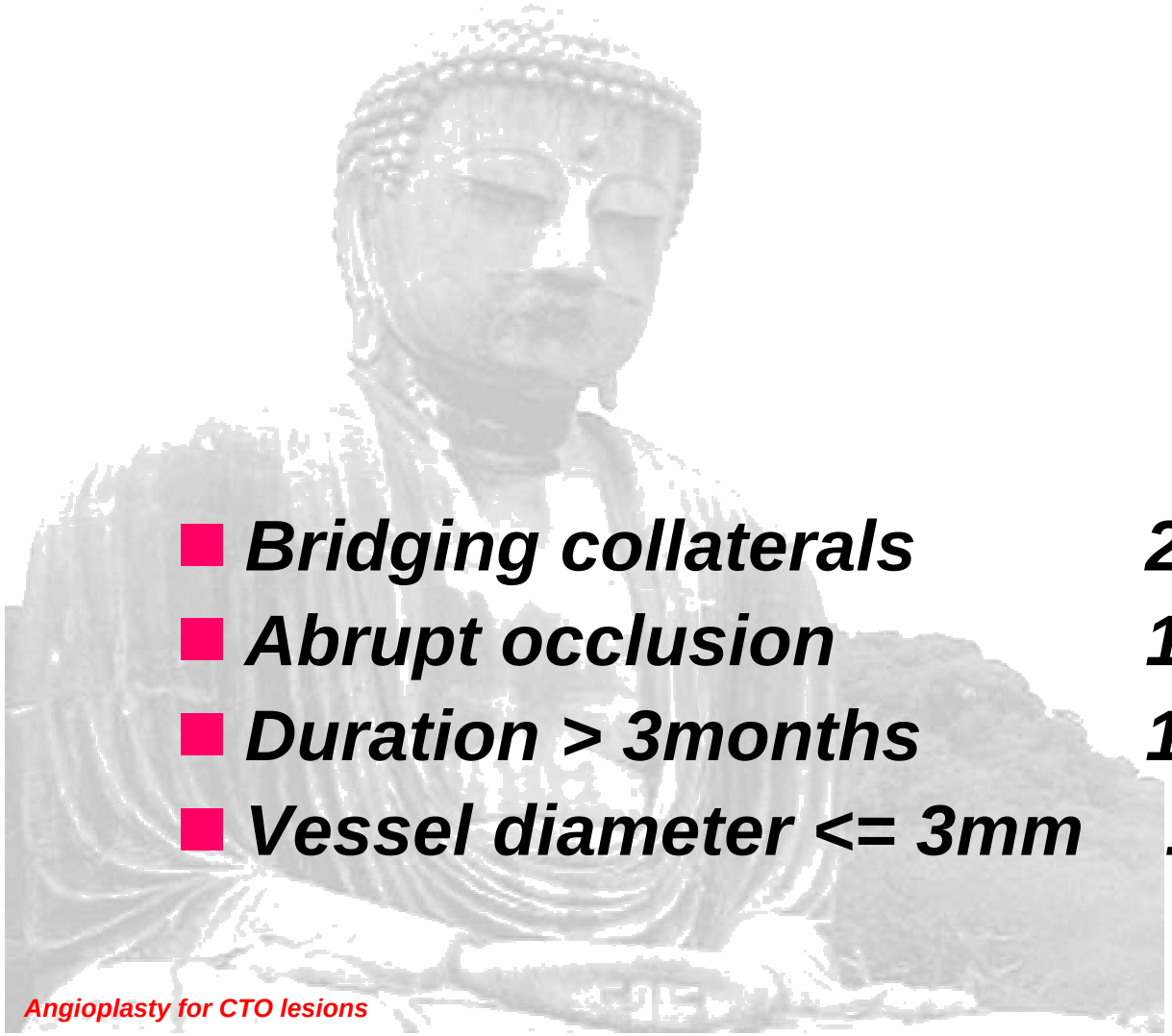
Ivanhoe RJ, et al. Percutaneous transluminal coronary angioplasty of chronic total occlusions. Circulation 1992; 85: 106-115.



	Failure (%)	p	OR
Number of vessel disease			
One	23.2%		1
Two	42.1%		1.8
Three	50.0%	0.001	3.2
Location			
LAD	23.5%		1
LCX	31.6%		1.3
RCA	39.5%	0.073	1.9
Functional occlusion			
Absent	40.4%		1
Present	21.7%	0.002	0.40

Predictors of procedural failure in CTO lesions

Tan KH, et al. Determinants of success of coronary angioplasty in patients with a chronic total occlusion. Br Heart J 1993; 70: 126-131.



	p	OR
Bridging collaterals	2.56	<0.001
Abrupt occlusion	1.29	<0.001
Duration > 3months	1.35	0.001
Vessel diameter <= 3mm	1.0	0.003

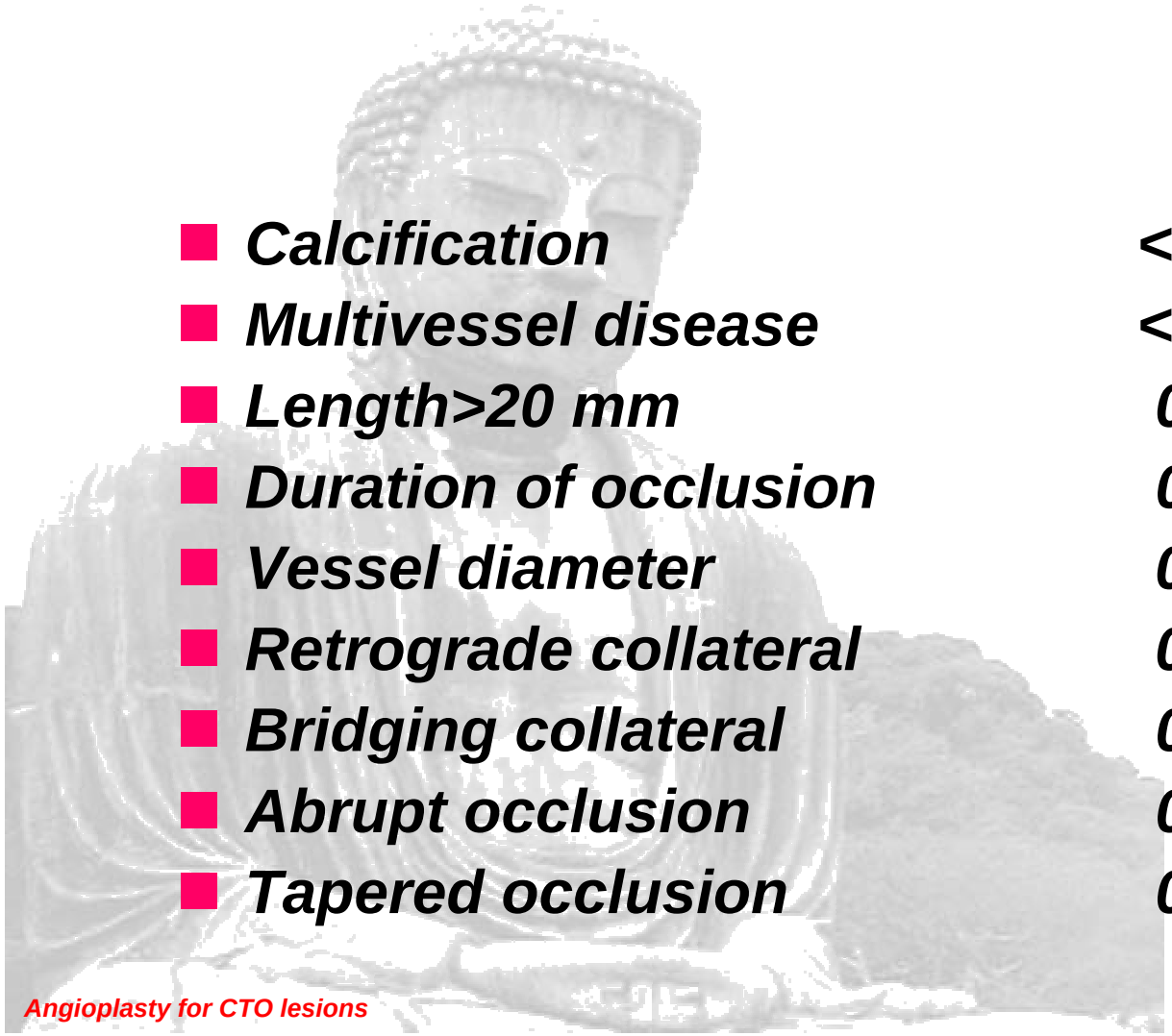
Predictors of procedural success in CTO lesions

Maiello L, Colombo A, et al. Coronary angioplasty of chronic occlusions: Factors predictive of procedural success. Am Heart J 1992; 124: 581-4.

	Success rate
Duration of occlusion	
● <= 1 month;	89%
● 1 to 3 months;	87%
● >=3 months;	45%
● Unknown;	60%
Morphology of occlusion	
● Tapered;	83%
● Abrupt;	51%
Length of occlusion	
● <=15mm;	71%
● >15mm;	60%
Bridging collateral	
● Present;	29%
● Absent;	67%

Predictors of procedural failure in CTO lesions

Noguchi T, et al. Percutaneous transluminal coronary angioplasty of chronic total occlusion. Catheter Cardiovasc Interv 2000; 49: 258-264.



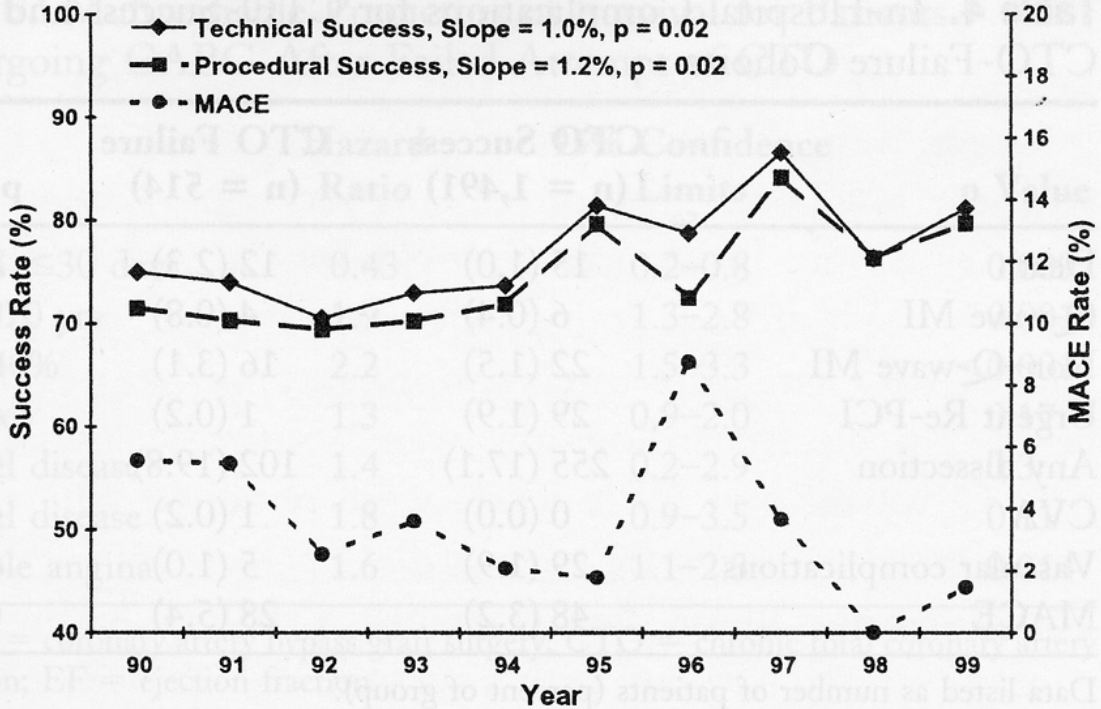
	p	OR
Calcification	<0.01	2.56
Multivessel disease	<0.01	2.11
Length>20 mm	0.05	1.72
Duration of occlusion	0.96	1.21
Vessel diameter	0.31	1.27
Retrograde collateral	0.58	0.87
Bridging collateral	0.96	1.10
Abrupt occlusion	0.30	1.59
Tapered occlusion	0.30	0.60

Predictors for failure in PCI for CTO lesions

- Lesion location:
  - Lesion in RCA is most difficult.
- Duration of occlusion:
  - 'More than 3 months' lesions are difficult.
- Triple vessel disease
- The presence of bridge collateral
- Length of occlusion
- Abrupt type occlusion
- Vessel size
  - 'Vessels <3mm in diameter' are difficult
- Proximal tortuousity
- Calcified lesions

Success Rates of PCI for CTO Lesions are gradually Improving in these several years

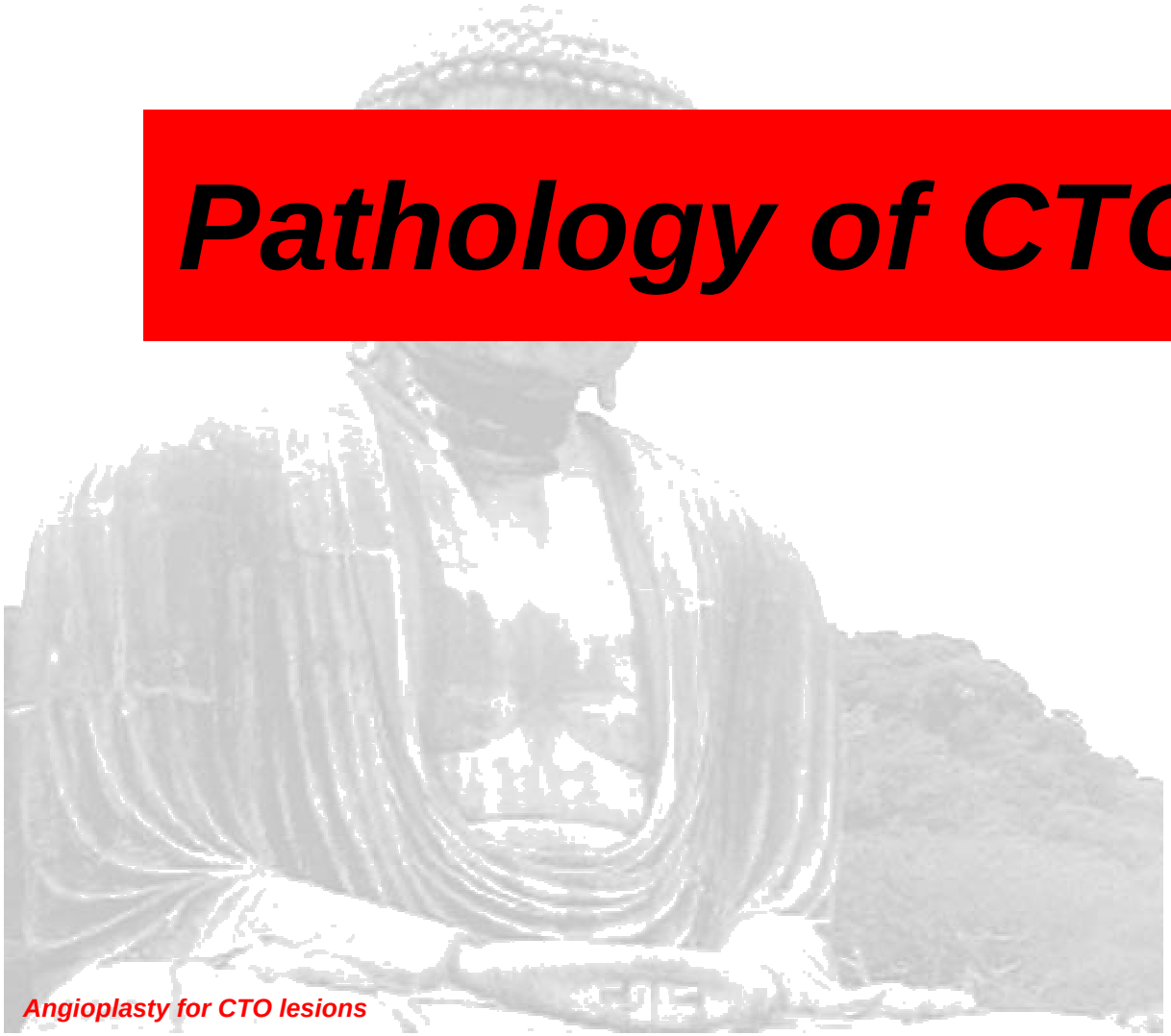
Suero JA, et al. J Am Coll Cardiol 2001; 38: 409-14.



	90	91	92	93	94	95	96	97	98	99
No. CTO PCI	144	128	157	111	96	113	80	82	76	69
No. Total PCI	1296	1255	1148	1018	964	952	923	976	922	932
CTO, %	11.1	10.2	13.7	10.9	10.0	11.9	8.7	8.4	8.2	7.4

Figure 1. Technical success, procedural success and major adverse cardiac event (MACE) rates since 1990. CTO = chronic total coronary artery occlusion; PCI = percutaneous coronary intervention.

Pathology of CTO lesions

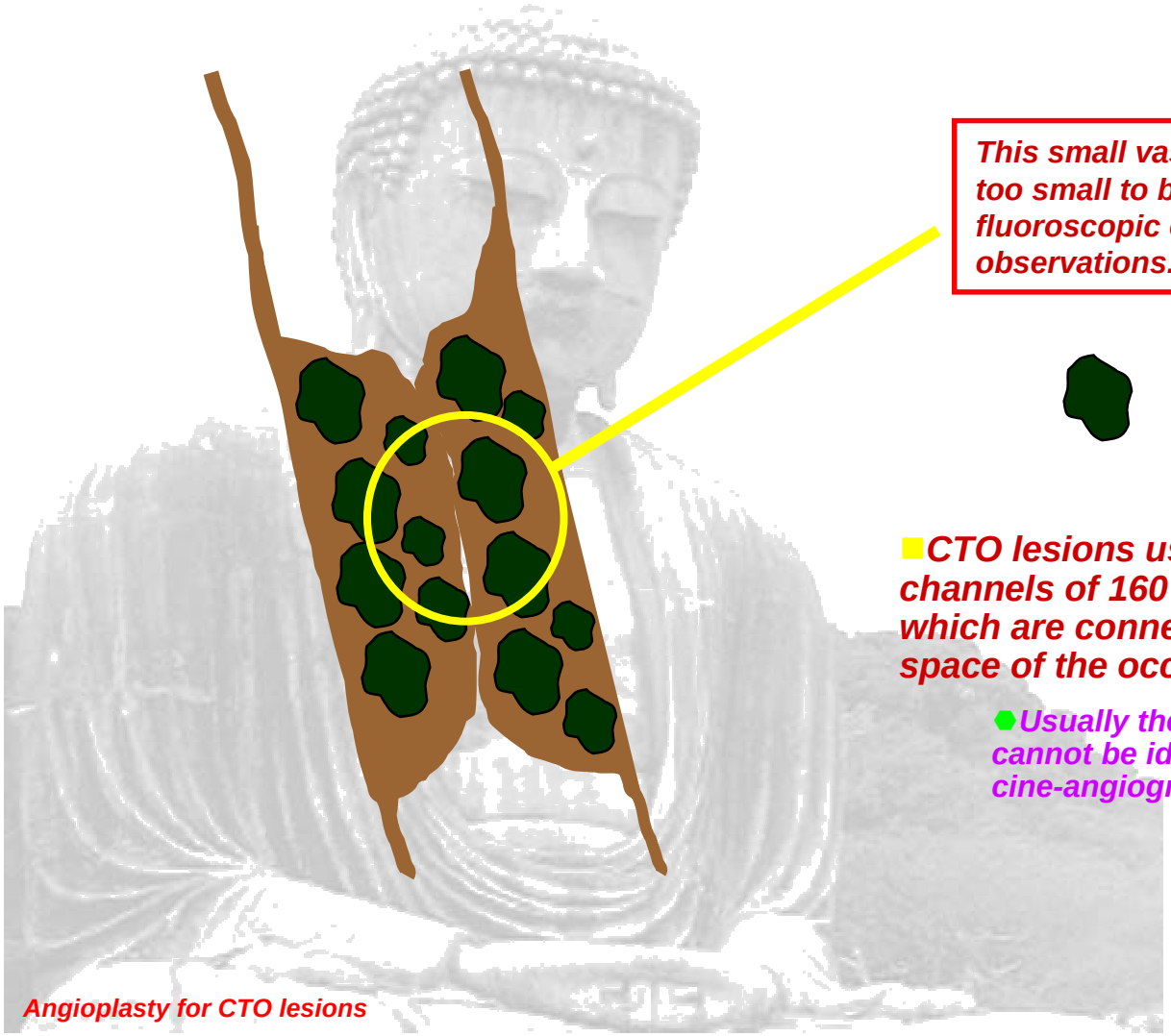


Pathology of CTO Lesions

Katsuragawa M, Fujiwara H, Miyamae M, Sasayama S. Histologic Studies in Percutaneous Transluminal Coronary Angioplasty for Chronic Total Occlusion: Comparison of Tapering and Abrupt Types of Occlusion and Short and Long Occluded Segments. J Am Coll Cardiol 1993; 21: 604-11

- **Pathological structure of CTO lesions:**
  - CTO lesions usually have small vascular channels of 160 to 230 microns in diameter, which are connecting to the proximal free space of the occlusions.
    - Usually these small vascular channels cannot be identified by a fluoroscopic or cine-angiographic observations.
  - Tapered-end CTO lese lesions usually have small vascular channels connecting between the lumens before and after occlusion.
  - When the small vascular channels are not connecting to the distal vascular lumen, they are usually connecting to small side branches or vaso vasorums.
  - The areas of loose fibrous tissues are surrounded by the area of dense fibrous tissues.

Schematic drawing for Pathology of CTO lesions



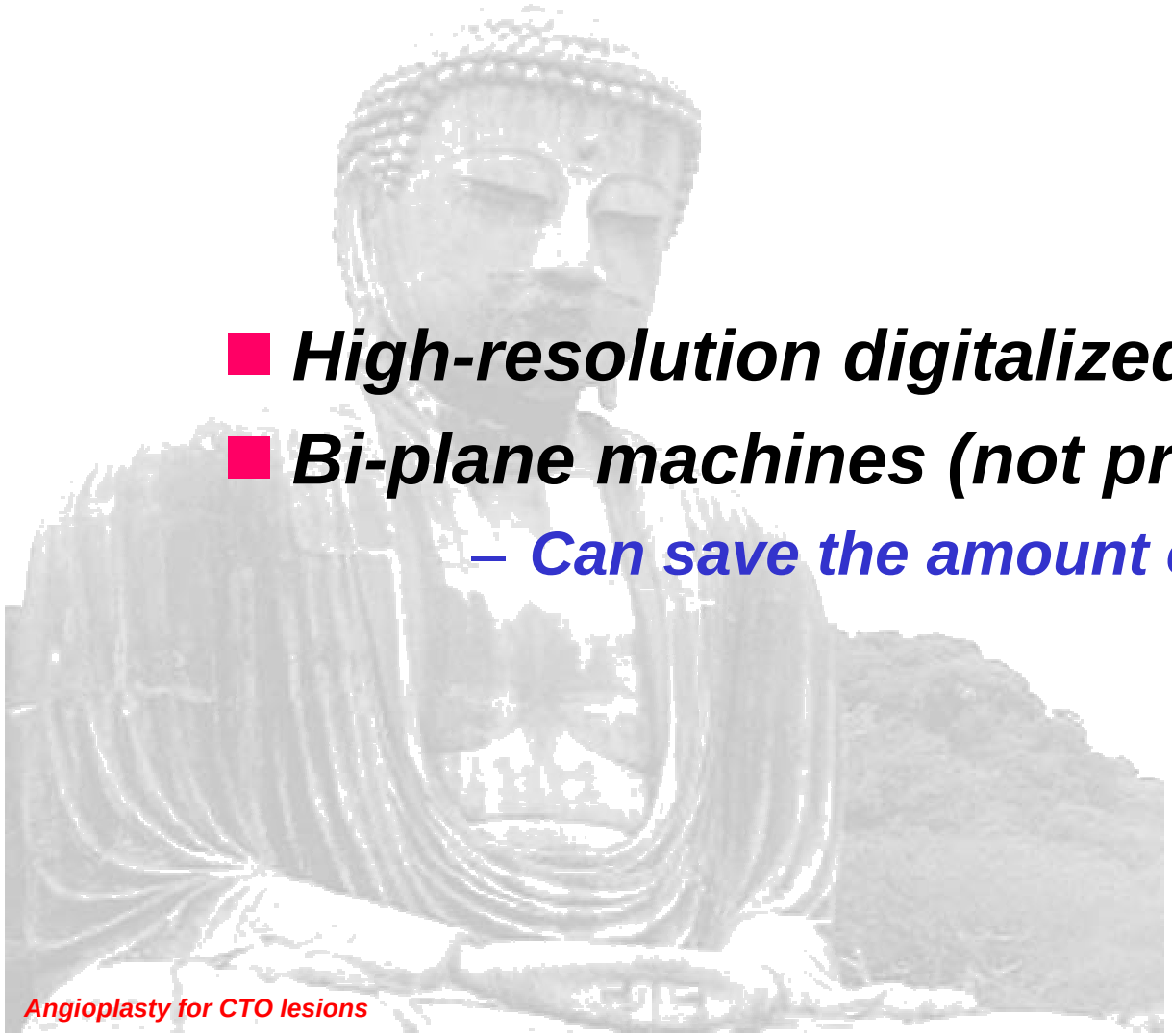
This small vascular channels are too small to be visualize by the fluoroscopic or cine-angiographic observations.

Islands of dense fibrous tissues

- *CTO lesions usually have small vascular channels of 160 to 230 microns in diameter, which are connecting to the proximal free space of the occlusions.*
  - *Usually these small vascular channels cannot be identified by a fluoroscopic or cine-angiographic observations.*

Device selection in CTO lesions

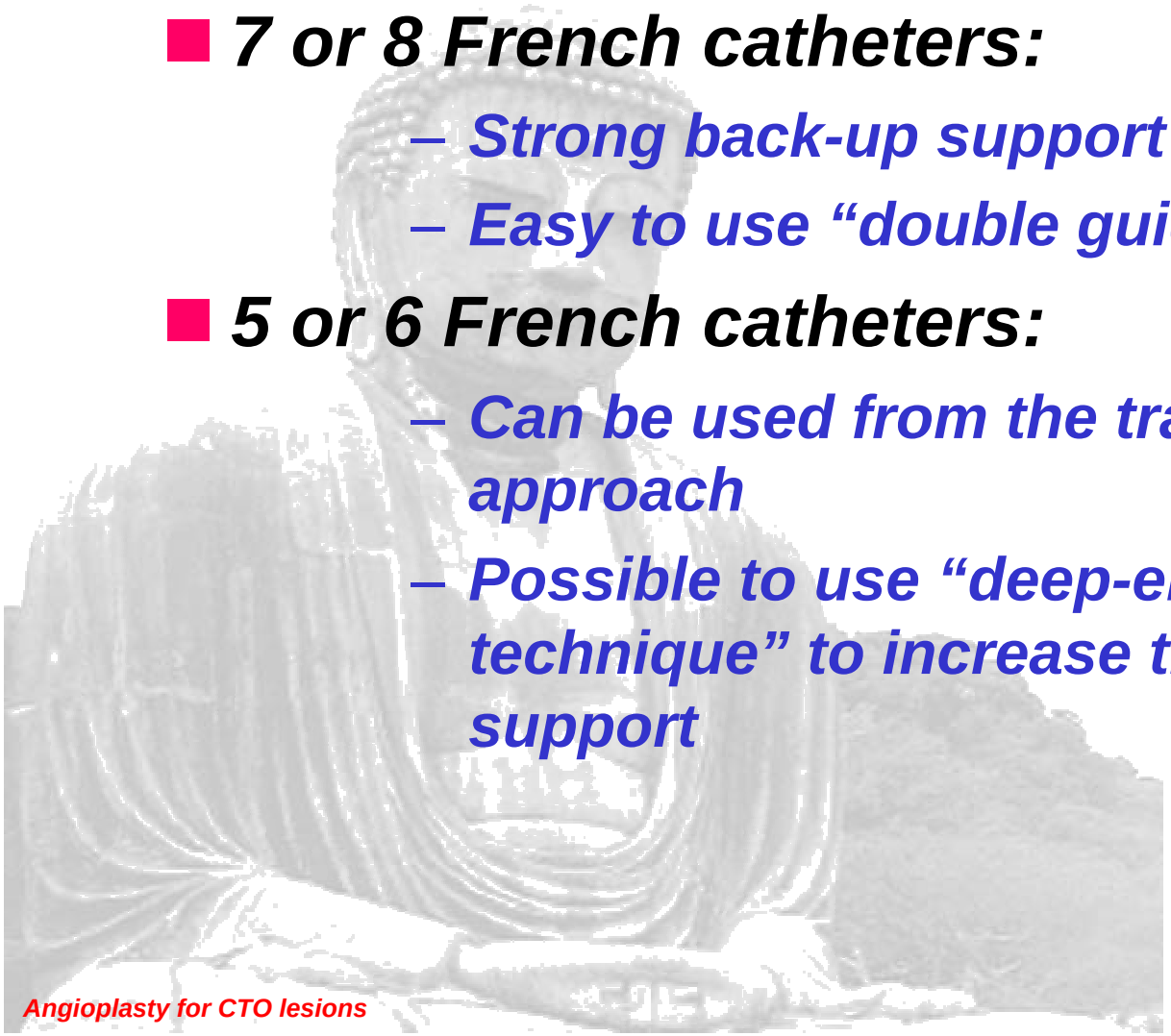
X-ray machines



- *High-resolution digitalized machine:*
- *Bi-plane machines (not prerequisite):*
  - *Can save the amount of contrast dye*

Guiding catheter selection

- *7 or 8 French catheters:*
  - *Strong back-up support*
  - *Easy to use “double guidewire technique”*
- *5 or 6 French catheters:*
  - *Can be used from the transradial approach*
  - *Possible to use “deep-engagement technique” to increase the back-up support*



Guiding catheter selection

- Lesions in left anterior descending artery
  - Judkins left – short tip
  - Voda left
  - EBU
  - XB
- Lesions in left circumflex artery
  - Amplatz left
  - Voda left
- Lesions in right coronary artery
  - Judkins right
  - Amplatz left
  - Multipurpose

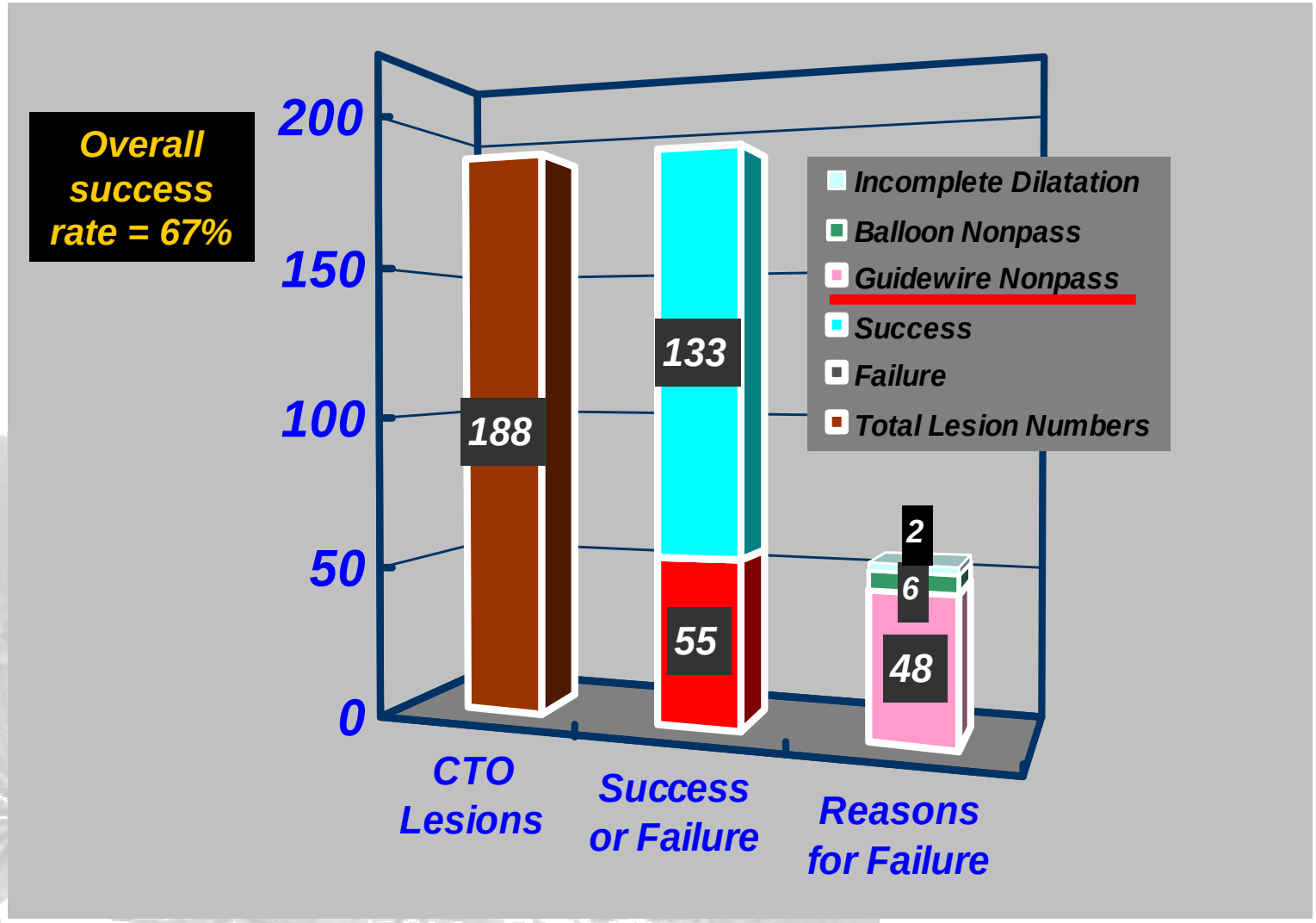
Over-the-wire system

- **Use of over-the-wire (OTW) system**
  - To provide better support to guidewires
  - To enable guidewire exchange
    - 1.5-mm OTW balloon
    - The following OTW support systems without balloons are preferable to OTW balloons, since they have distal shaft softer than the latter and align a guidewire more easily with coronary arteries.
      - Transit (Cordis)
      - Prowler (Cordis)
      - Excelsior (Boston Scientific)
      - Interpass (TERUMO, Japan)
      - Ichiban-Yari (Kaneka, Japan)

Guidewire selection

- **Regular guide wires:**
  - BMW guide wire (GUIDANT)
  - Intermediate guide wire (GUIDANT)
  - Standard guide wire (GUIDANT)
  - Very stiff guidewires - Miracle 3, 6, 12, 15 (Asahi Intech, JAPAN)
- **Hydrophilic coating guide wires:**
  - Choice-PT (Boston-Scientific)
  - Whisper-LS & MS (GUIDANT)
  - Shinobi (Cordis)
  - Crosswire-NT (TERUMO)
- **Tapered-tip guide wires:**
  - Cross-it 100, 200, 300, 400 (GUIDANT)
  - Conquest (Asahi Intech, JAPAN)

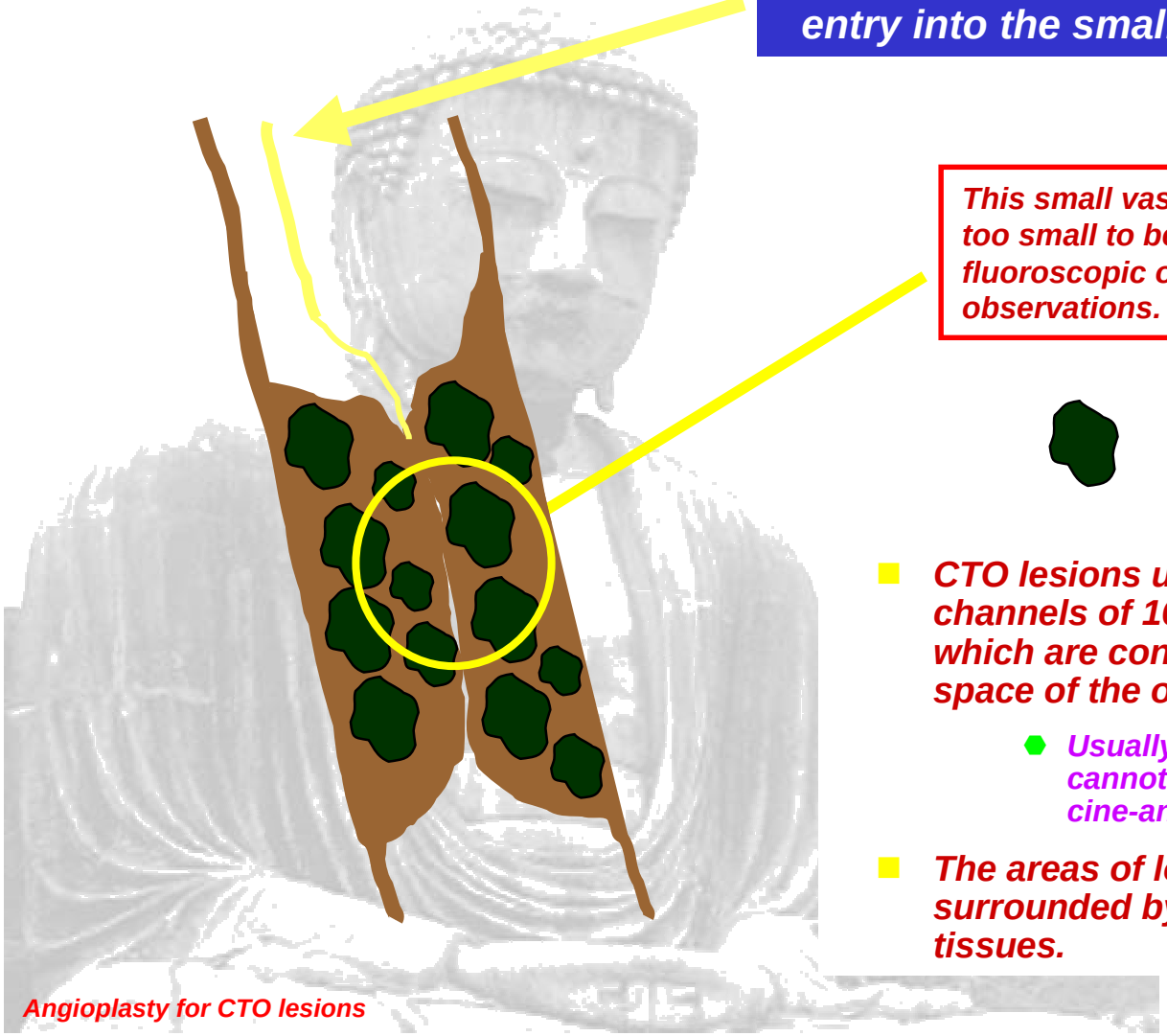
Reasons for Failure in PCI for CTO Lesion in ShonanKamakura General Hospital between April 1997 and December 1999



Guidewire selection for CTO lesions

- Tapered-tip guidewires -

Tapered-tip guide wire can facilitate the entry into the small vascular channel!

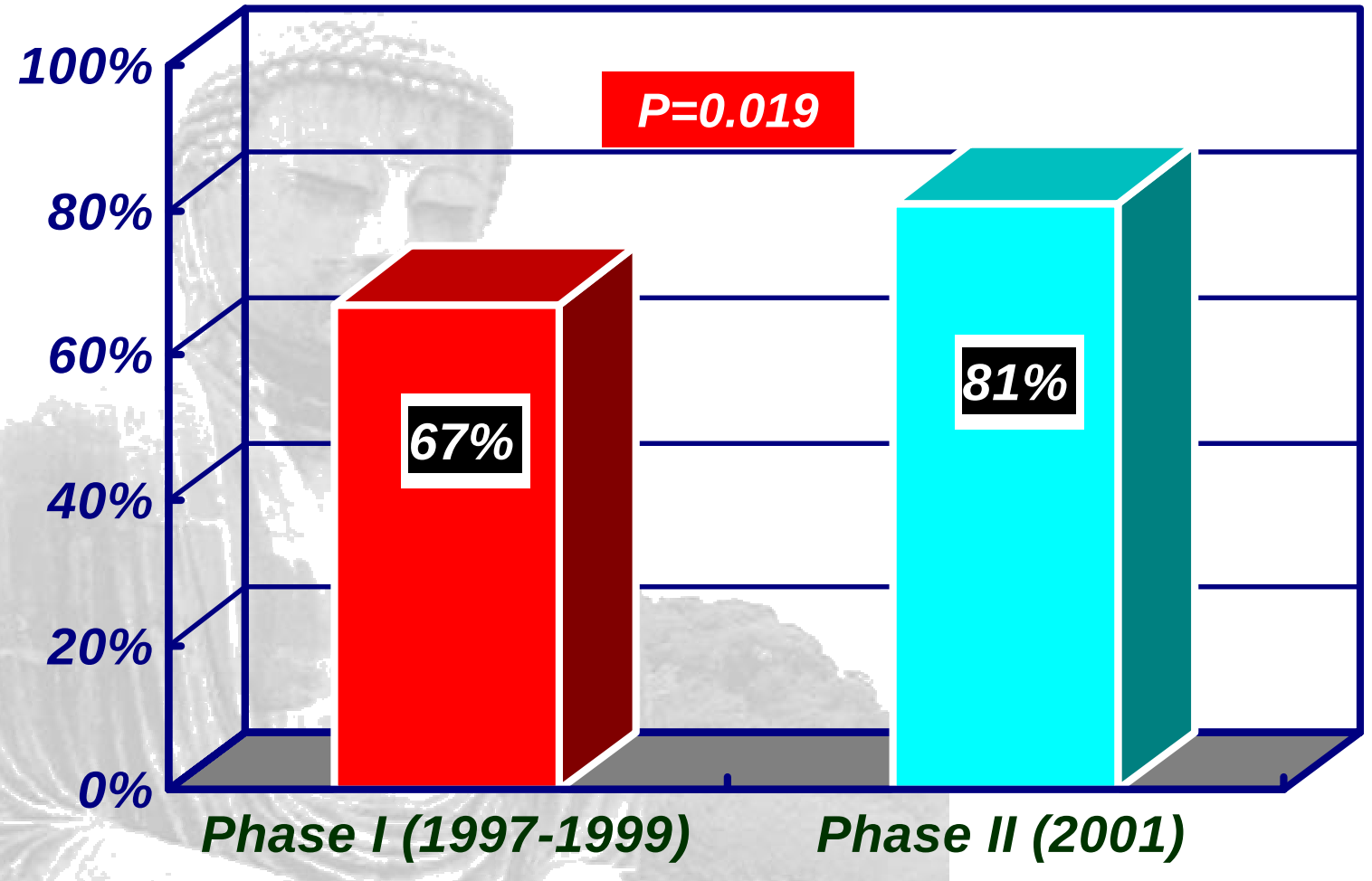


This small vascular channels are too small to be visualize by the fluoroscopic or cine-angiographic observations.

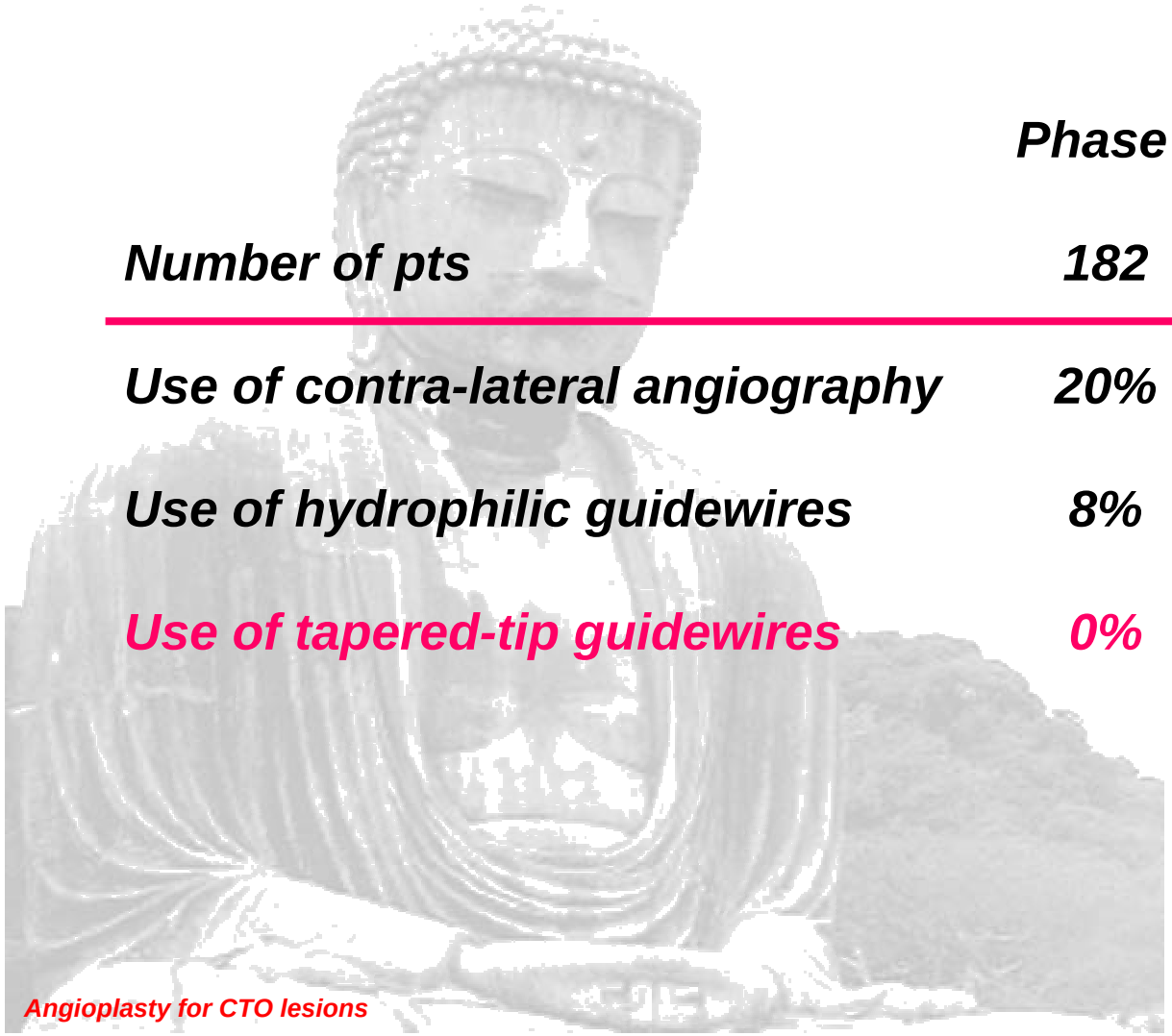
Islands of dense fibrous tissues

- **CTO lesions usually have small vascular channels of 160 to 230 microns in diameter, which are connecting to the proximal free space of the occlusions.**
  - *Usually these small vascular channels cannot be identified by a fluoroscopic or cine-angiographic observations.*
- **The areas of loose fibrous tissues are surrounded by the area of dense fibrous tissues.**

Success rates in PCI for CTO lesions was improved in ShonanKamakura G Hospital



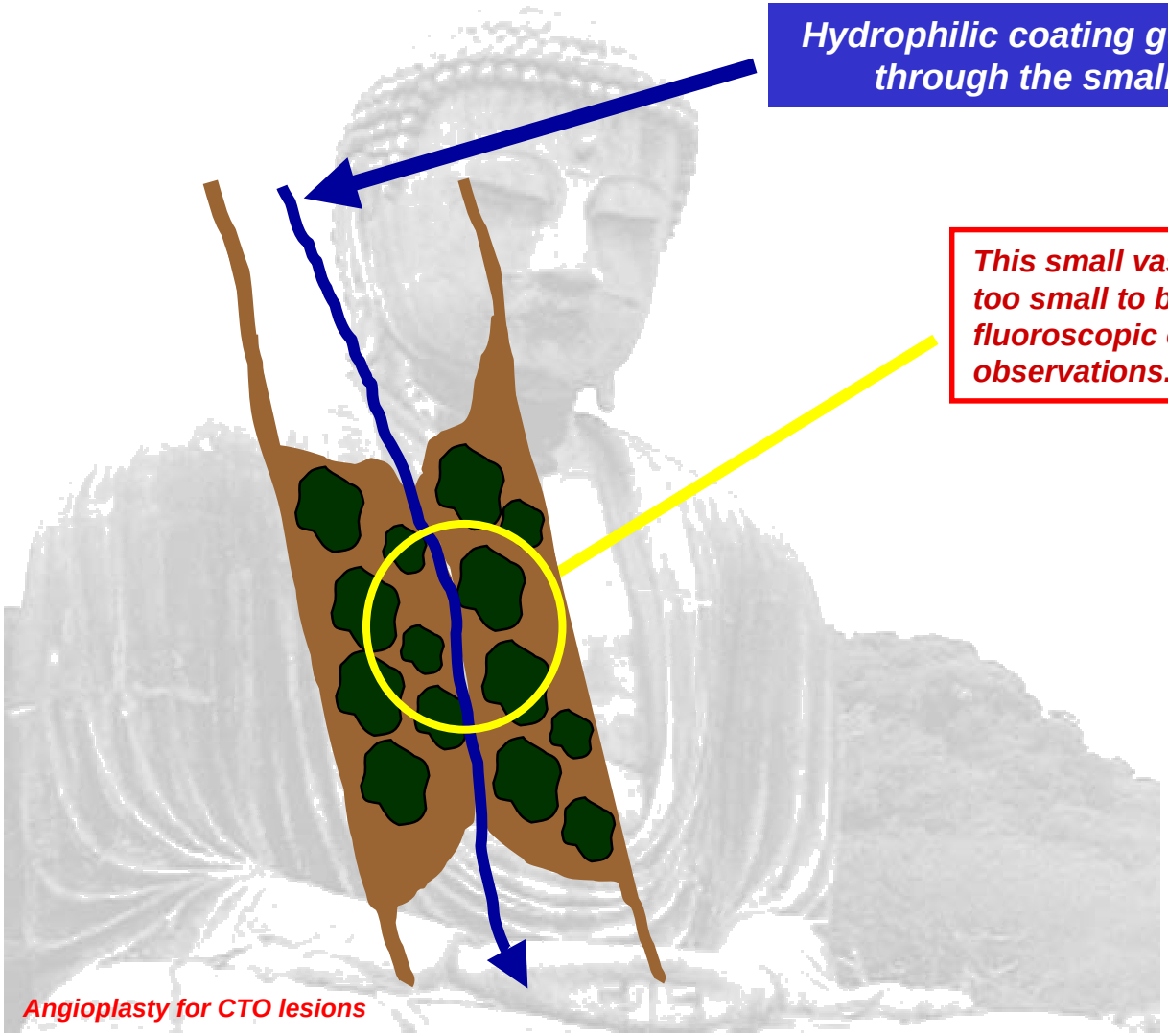
Technical characteristics in Phase I and II periods



	Phase I	Phase II	p
Number of pts	182	80	
Use of contra-lateral angiography	20%	23%	NS
Use of hydrophilic guidewires	8%	6%	NS
Use of tapered-tip guidewires	0%	60%	<0.001

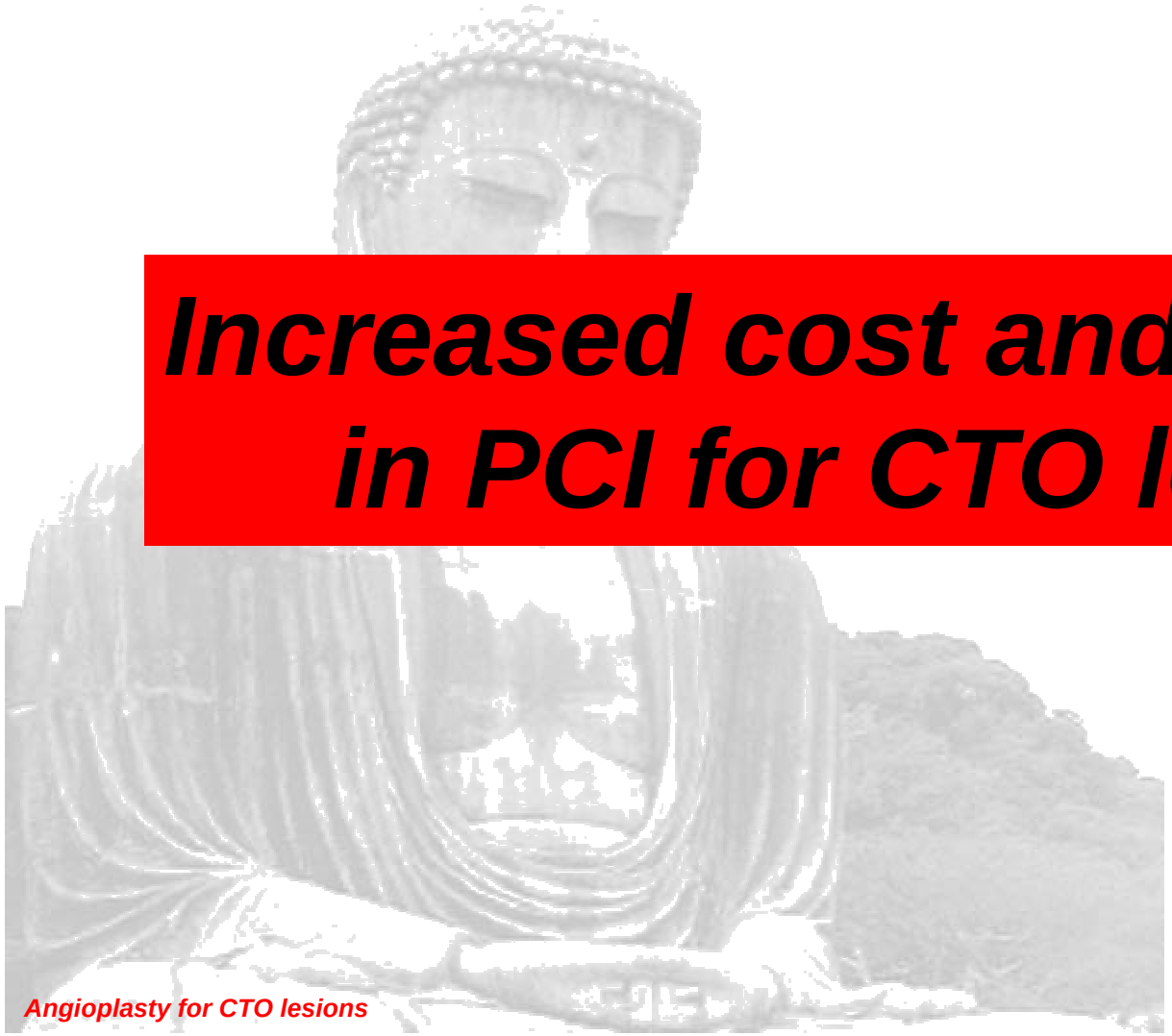
Guidewire selection for CTO lesions

- Hydrophilic-coating guidewires -

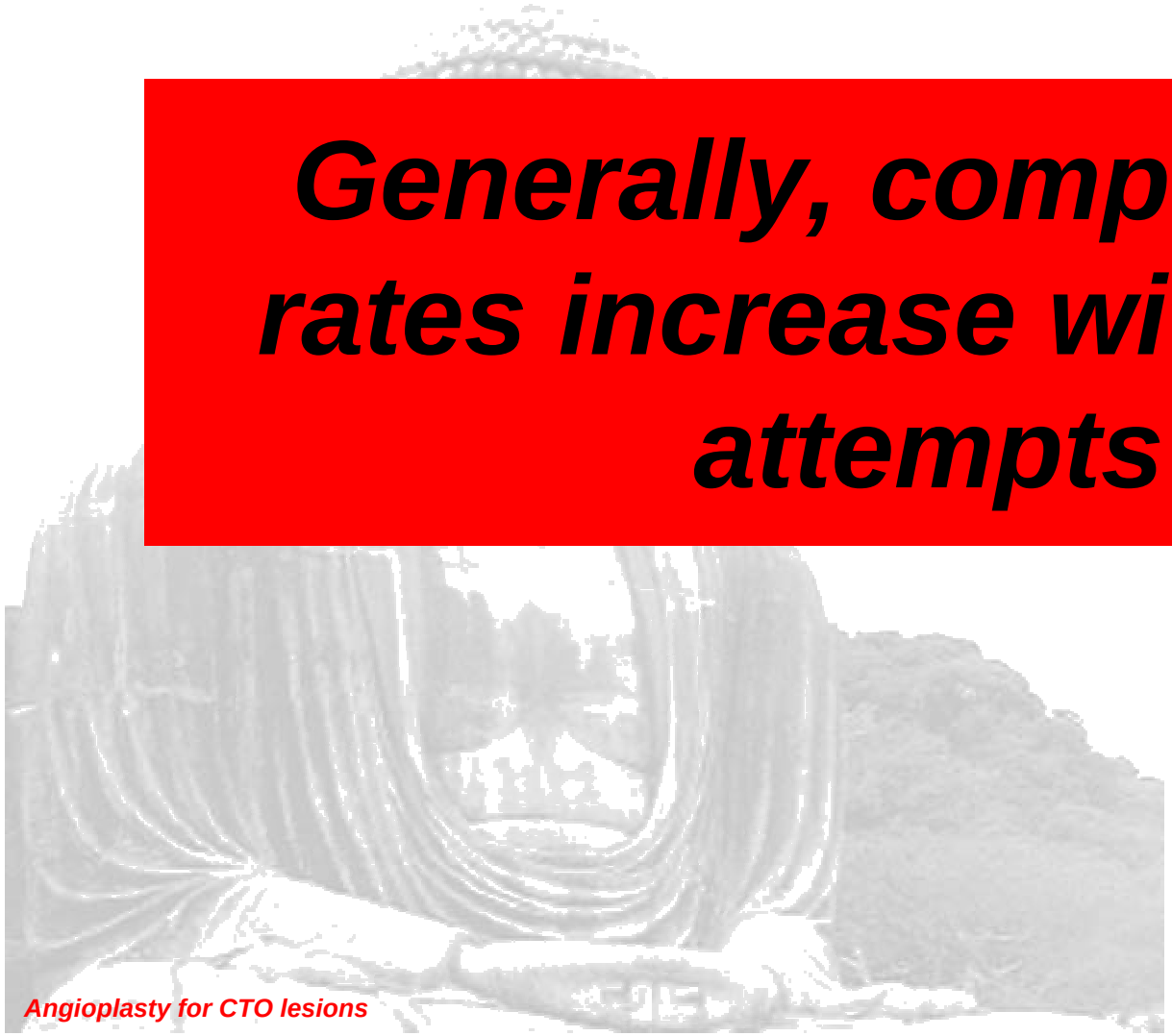


Hydrophilic coating guide wire can easily go through the small vascular channel.

This small vascular channels are too small to be visualize by the fluoroscopic or cine-angiographic observations.



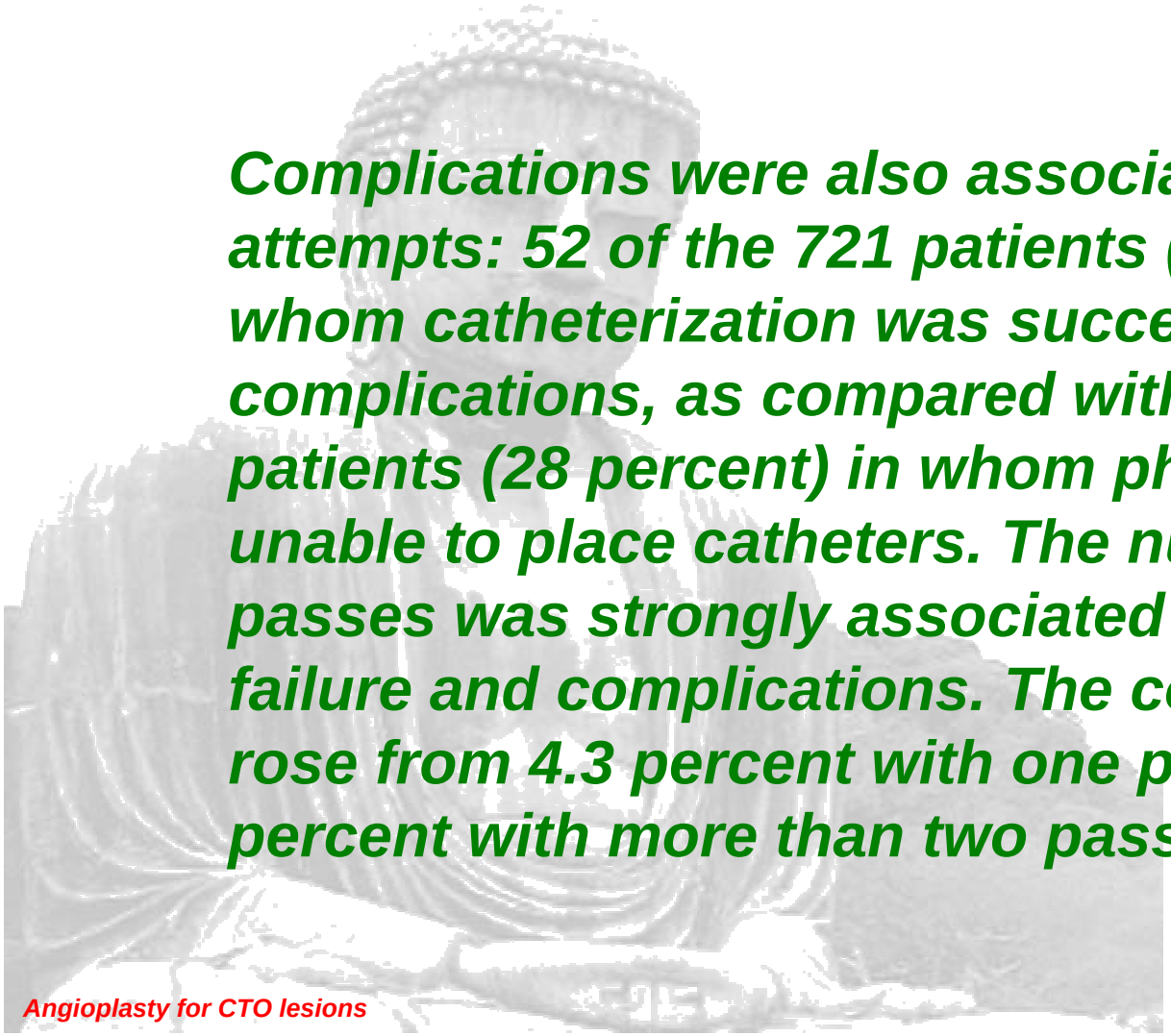
Increased cost and radiation in PCI for CTO lesions



Generally, complication rates increase with failed attempts

Complication rates increase with failed attempts

Paul F. Mansfield, et al. Complications and Failures of Subclavian-Vein Catheterization. N Engl J Med 1994; 331:1735-1738.

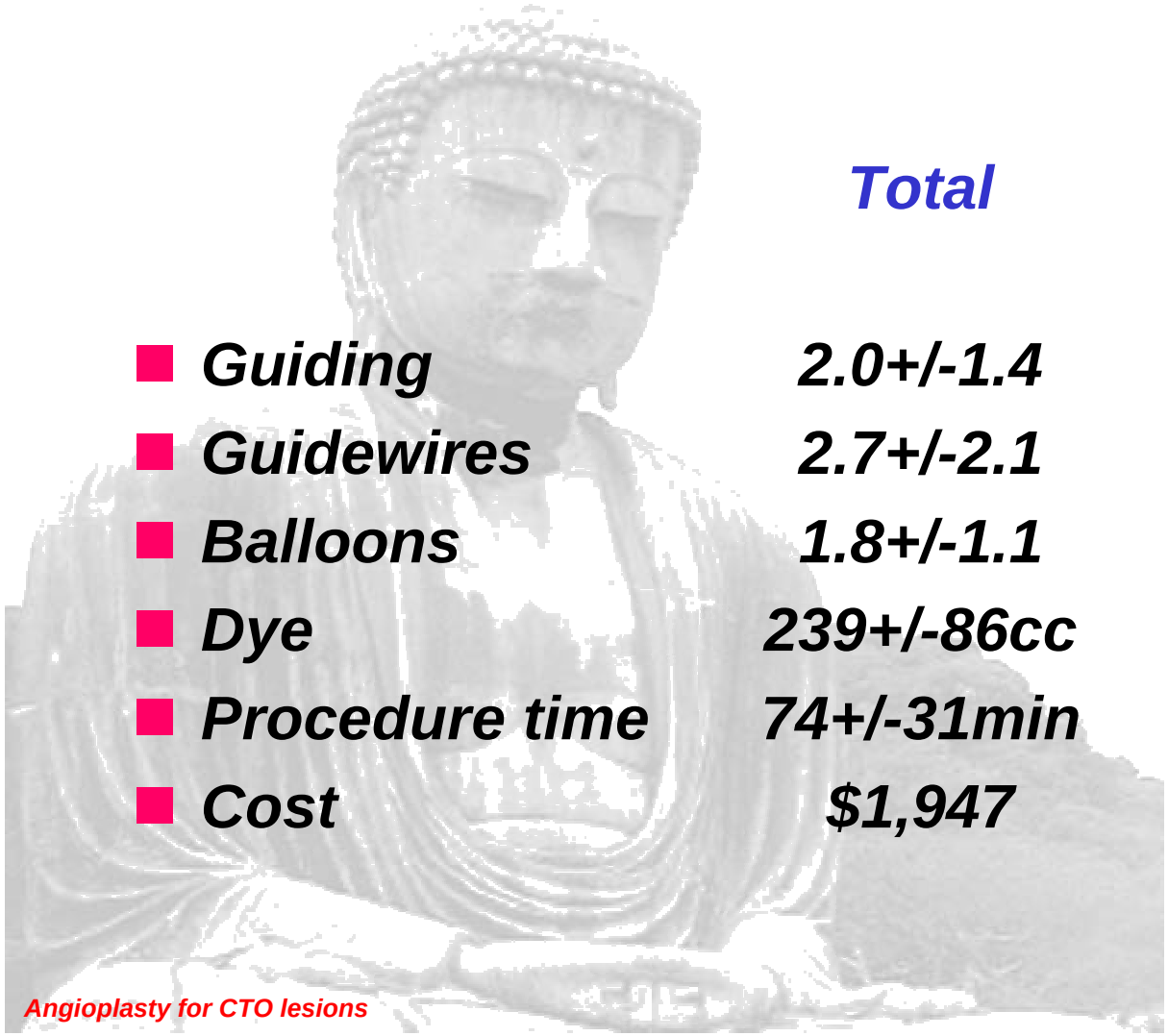


Complications were also associated with failed attempts: 52 of the 721 patients (7.2 percent) in whom catheterization was successful had complications, as compared with 28 of the 100 patients (28 percent) in whom physicians were unable to place catheters. The number of needle passes was strongly associated with the rates of failure and complications. The complication rate rose from 4.3 percent with one pass to 24.0 percent with more than two passes.

Increased cost in PCI for CTO lesions

Increased cost during PCI for CTO lesions

Malcolm R, et al. Balloon angioplasty of chronic total coronary artery occlusions: What does it cost in radiation exposure, time, and materials. Cathet Cardiovasc Diagn 1992; 25: 10-15.



	Total	Subtotal	p
Guiding	2.0+/-1.4	1.5+/-1.0	0.005
Guidewires	2.7+/-2.1	1.5+/-1.1	<0.001
Balloons	1.8+/-1.1	1.3+/-0.6	<0.001
Dye	239+/-86cc	234+/-79cc	NS
Procedure time	74+/-31min	59+/-24min	0.06
Cost	$1,947	$1,398	

Prolonged procedures are harmful to kidney function

Prolonged procedure is harmful to kidney functions

Lip GY, et al. Changes in renal function with percutaneous transluminal coronary angioplasty. Int J Cardiol 1999; 70: 127-31.

- *There was a small rise in serum creatinine pre- and post-PTCA of borderline significance (mean change +5.8 micromol/l, P=0.051). Of the whole cohort, 65 patients (63%) had a rise in mean serum creatinine, whilst 45 (43%) showed a rise in serum urea levels. This deterioration in renal function was related to a difference in the procedure duration, but there were no statistically significant differences in mean age or volume of contrast media (Iopamide 340) between patients with or without deterioration in renal function.*

Increased contrast volume is harmful to kidney functions

Baumgart D, et al. High-volume nonionic dimeric contrast medium: first experiences during complex coronary interventions. Cathet Cardiovasc Diagn 1997; 40: 241-6.

- ***Retrospectively, 25 consecutive patients (age 56 +/- 10 yr) with normal renal and cardiac function receiving > 500 ml of the nonionic dimeric contrast medium iodixanol during complex coronary interventions***
  - ***Mean serum creatinine rose from 0.9 +/- 0.2 mg/dl to 1.1 +/- 0.2 mg/dl (P < 0.05) after 2 days of coronary intervention.***

Increased contrast volume is harmful to kidney functions

Kahn JK, Rutherford BD, McConahay DR, Johnson WL, Giorgi LV, Shimshak TM, Hartzler GO.

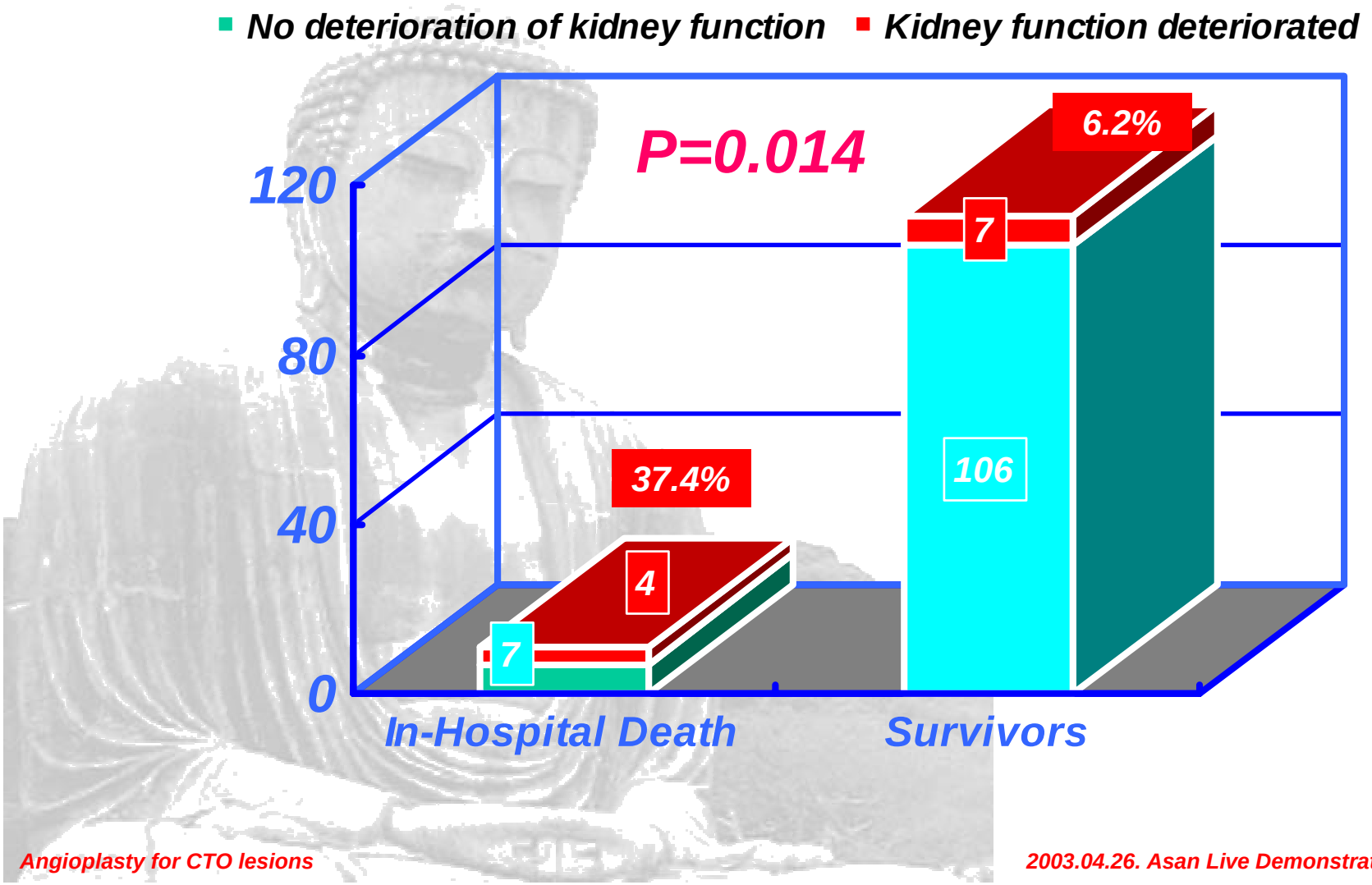
High-dose contrast agent administration during complex coronary angioplasty. Am Heart J 1990; 120: 533-6.

- *The 54 patients 730 consecutive patients (7%) requiring contrast agent doses >= 400 ml were examined. The mean contrast dose in this group was 496 +/- 76 ml (range 400 to 785 ml). Their mean age was 63 +/- 11 years (range 36 to 83 years), 10 patients had diabetes mellitus (19%), and four patients had a baseline creatinine level greater than or equal to 1.5 mg/dl (7%).*
  - *Following coronary angioplasty, the serum creatinine rose from 1.1 +/- 0.2 to 1.2 +/- 0.3 (p = 0.08). The creatinine rose >= 0.5 mg/dl in 6 patients (11%) and >= 1.0 mg/dl in 1 patient (2%).*

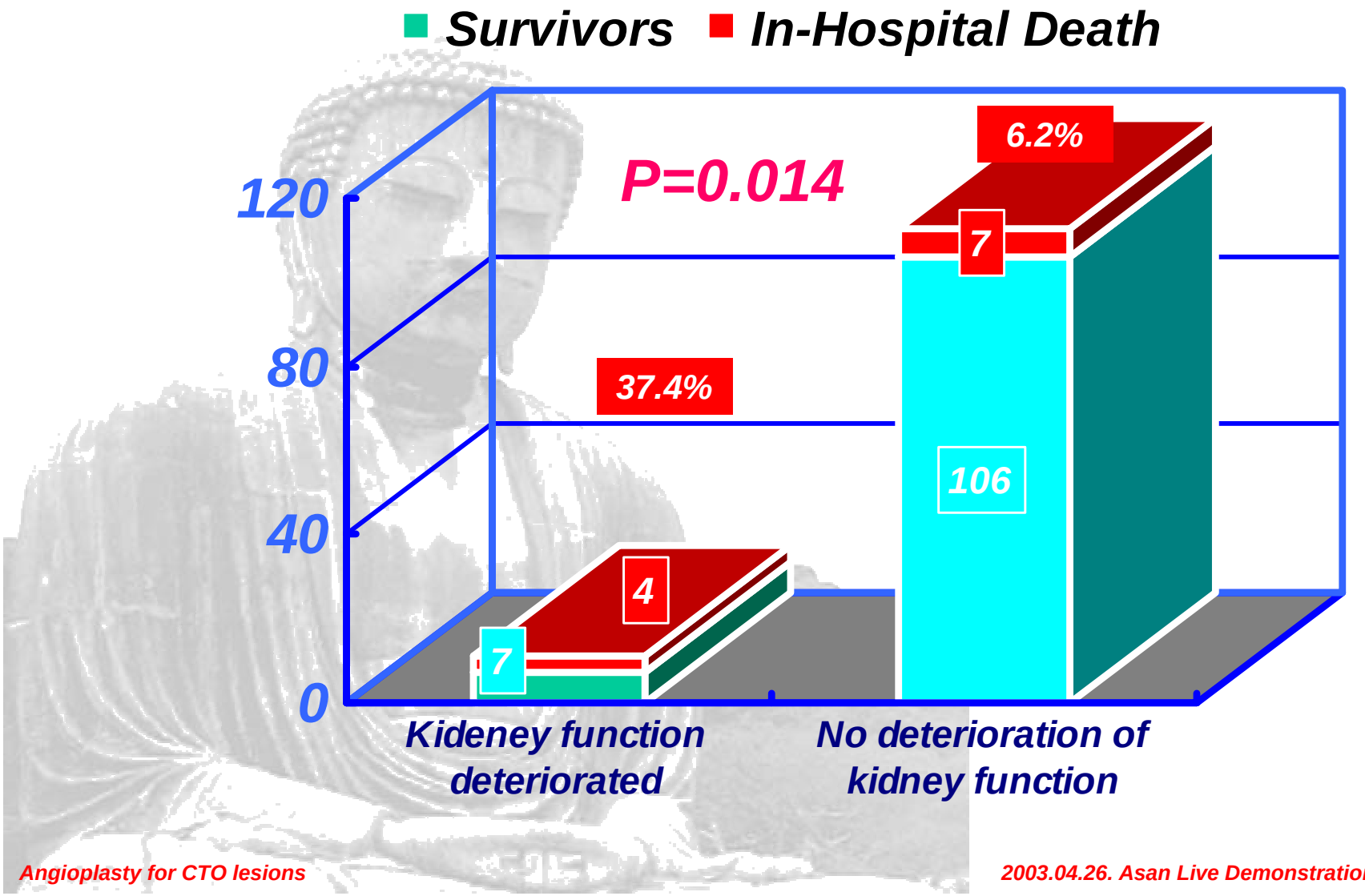
Methods

- **Patient population:**
  - Total of 124 patients with acute myocardial infarction within 12 hours from onset, who received emergency PCI in ShonanKamakura General Hospital between July 2001 and June 2002.
    - In-hospital mortality:
      - 8.9%

Deterioration of kidney function after emergency PCI is a strong predictor for poor prognosis in patients with AMI



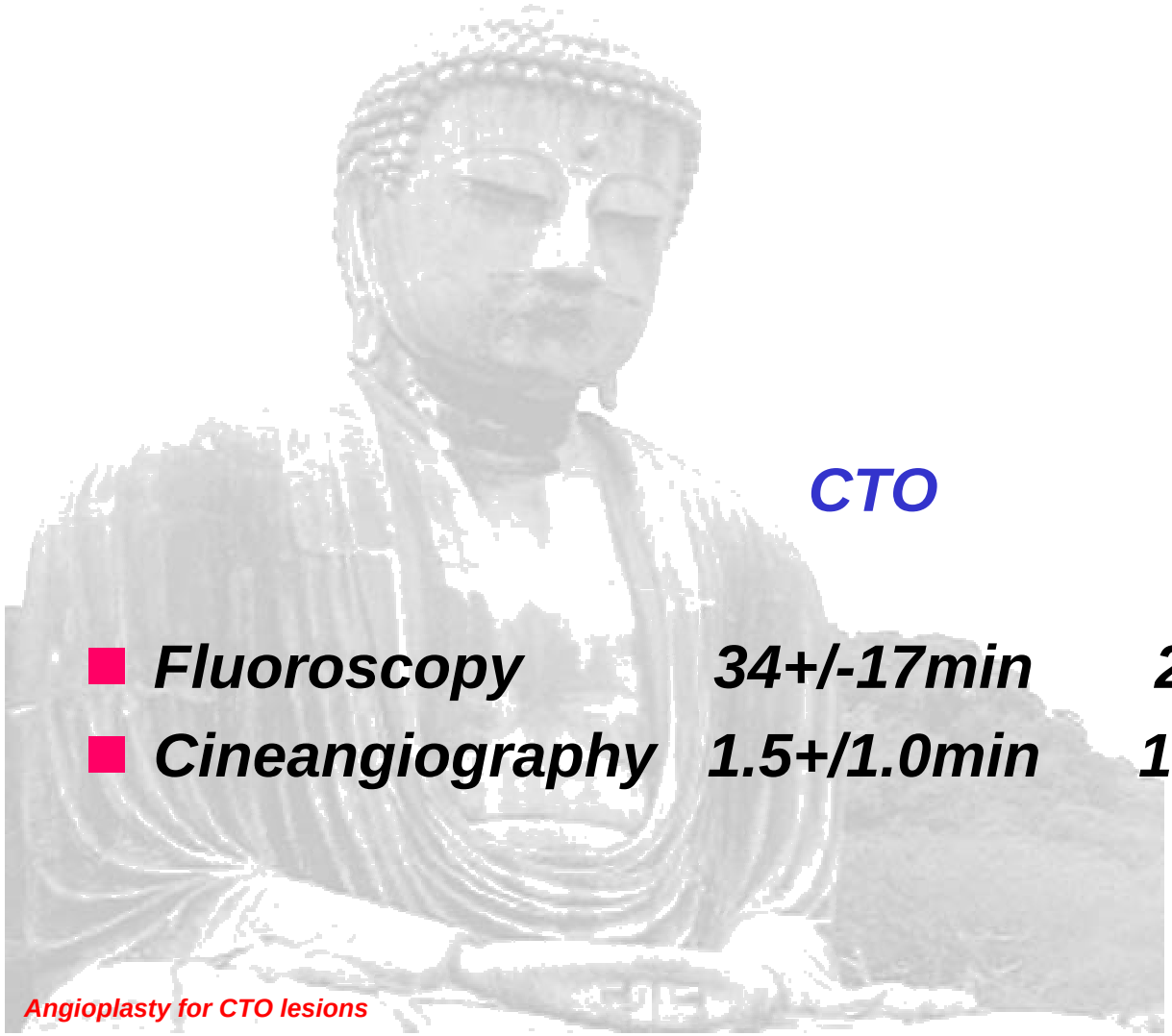
Deterioration of kidney function after emergency PCI is a strong predictor for poor prognosis in patients with AMI



Increased radiation exposure

Increased radiation exposure during PCI for CTO lesions

Malcolm R, et al. Balloon angioplasty of chronic total coronary artery occlusions: What does it cost in radiation exposure, time, and materials. Cathet Cardiovasc Diagn 1992; 25: 10-15.

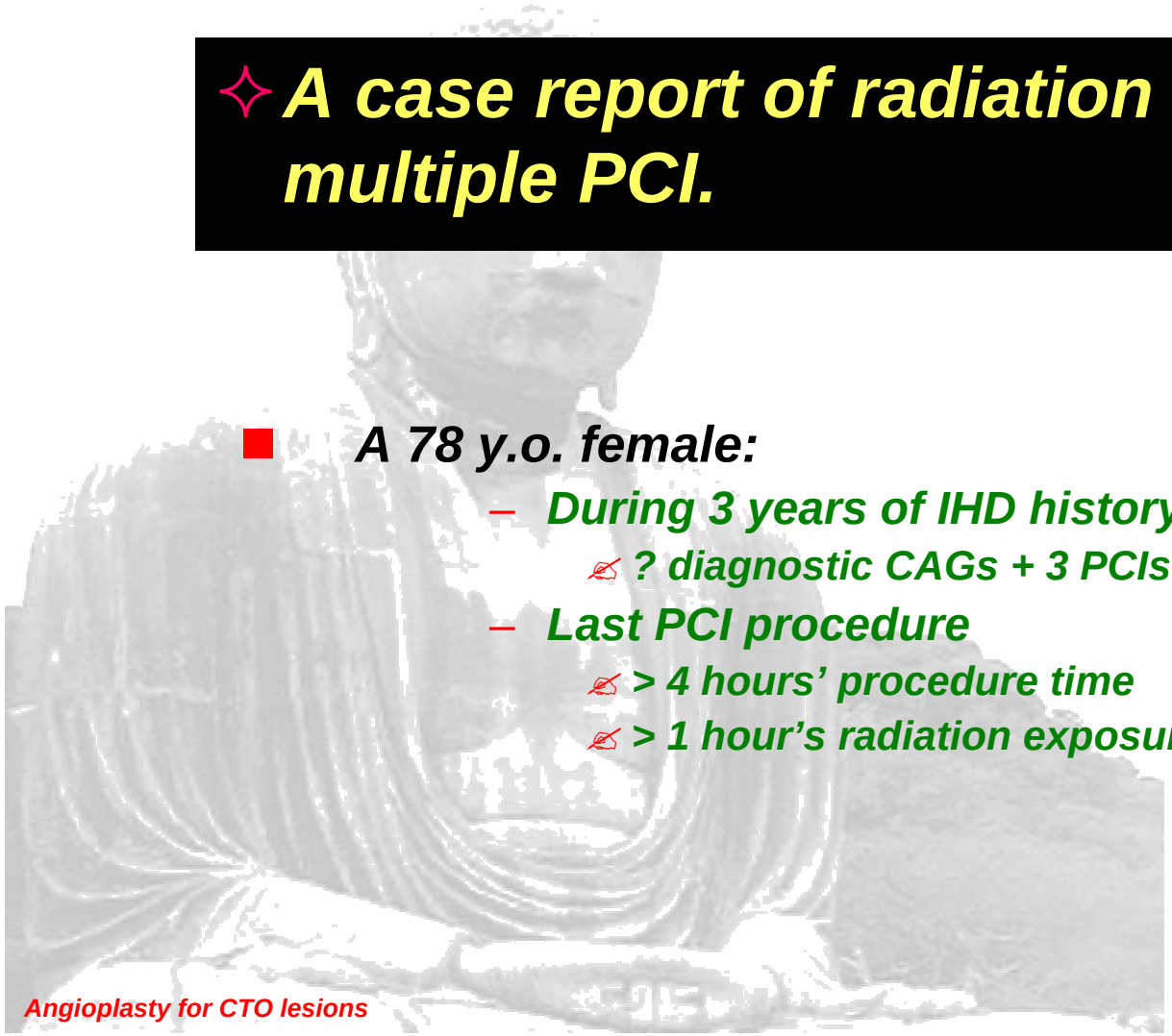


	CTO	non CTO	p
Fluoroscopy	34+/-17min	23+/-15min	0.0004
Cineangiography	1.5+/1.0min	1.6+/-0.6min	NS

Radiation dermatitis after PCI

Schmoor P, et al. Chronic radiodermatitis after cardiac catheterization. Catheter Cardiovasc Interv 2001; 52: 235-6.

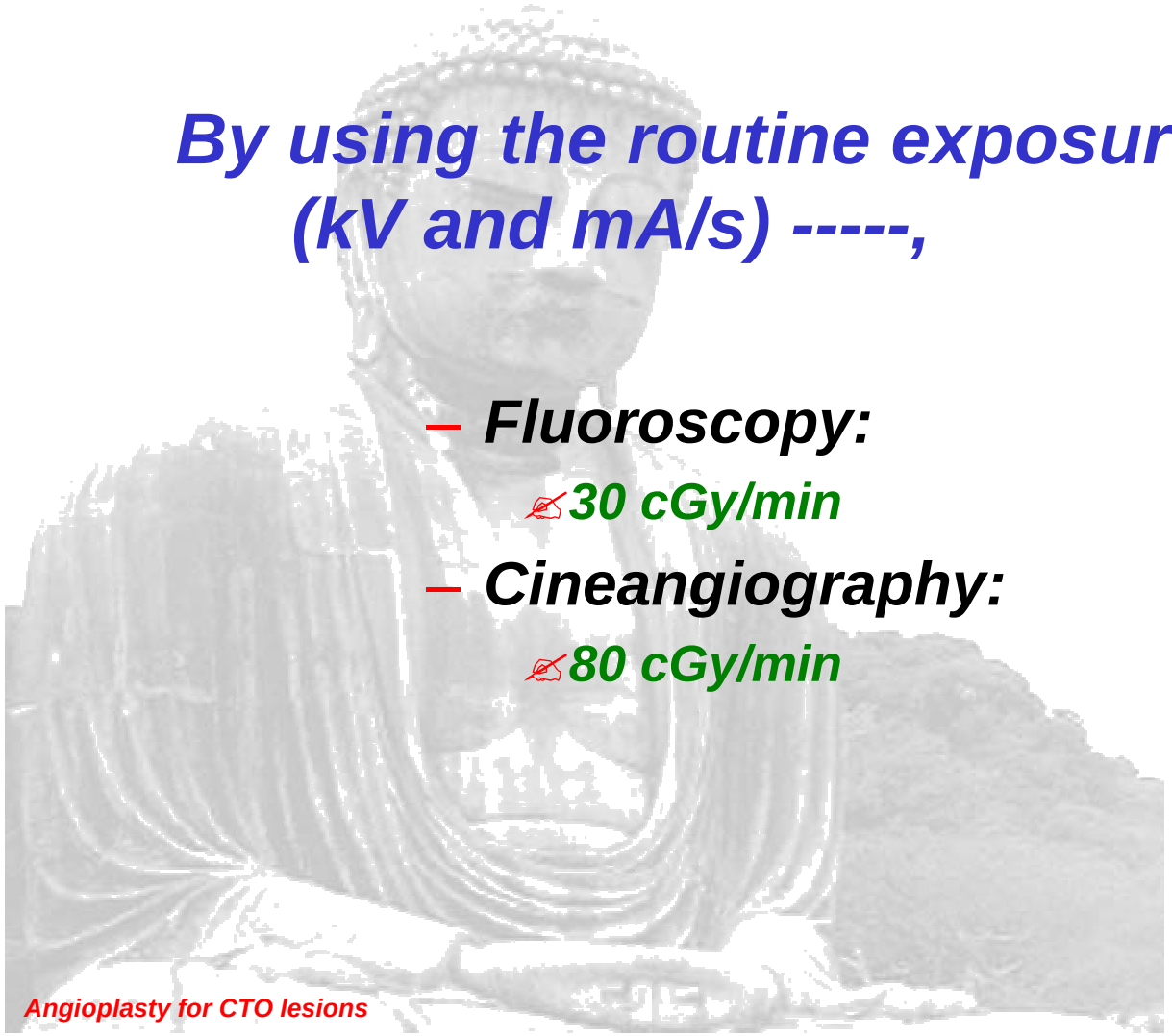
✧ A case report of radiation dermatitis after multiple PCI.



- A 78 y.o. female:
  - During 3 years of IHD history
    - ? diagnostic CAGs + 3 PCIs
  - Last PCI procedure
    - > 4 hours' procedure time
    - > 1 hour's radiation exposure time

How much radiation dose during PCI?

Kawakami T, et al. Chronic radiodermatitis following repeated percutaneous transluminal coronary angioplasty. Br J Dermatol 1999; 141: 150-3.

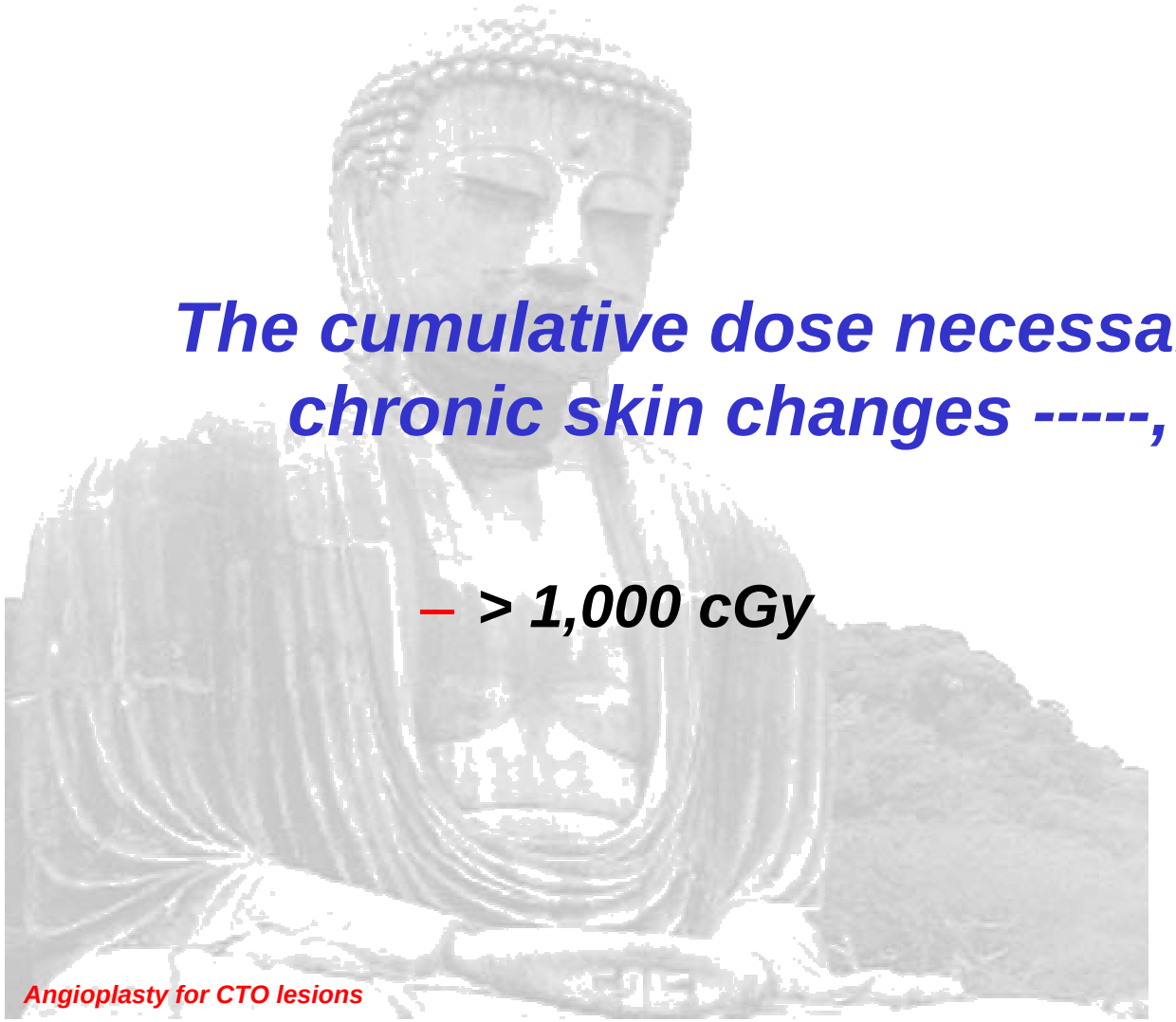


By using the routine exposure variables (kV and mA/s) -----,

- **Fluoroscopy:**
  - 30 cGy/min
- **Cineangiography:**
  - 80 cGy/min

How much radiation dose during PCI?

Turesson I, Notter G. Dose-response and dose-latency relationships for human skin after various fractionation schedules. Br J Cancer Suppl 1986;7:67-72.



The cumulative dose necessary to induce chronic skin changes -----,

– ***> 1,000 cGy***

Radiation dermatitis after PCI

Kawakami T, et al. Chronic radiodermatitis following repeated percutaneous transluminal coronary angioplasty. Br J Dermatol 1999; 141: 150-3.

- *Three cases report from Toho University Hospital, Japan.*
- *All 3 patients had undergone lengthy PTCA for CTO lesions on several occasions. The skin eruption was characterized by an atrophic rectangular plaque on the left upper back, presenting as mottled hyper- and hypopigmentation with reticulate telangiectasia. Histologically, the eruption demonstrated epidermal atrophy, hyalinized and irregularly stained collagen, and telangiectasia of superficial vessels in the dermis.*

How much radiation dose during PCI?

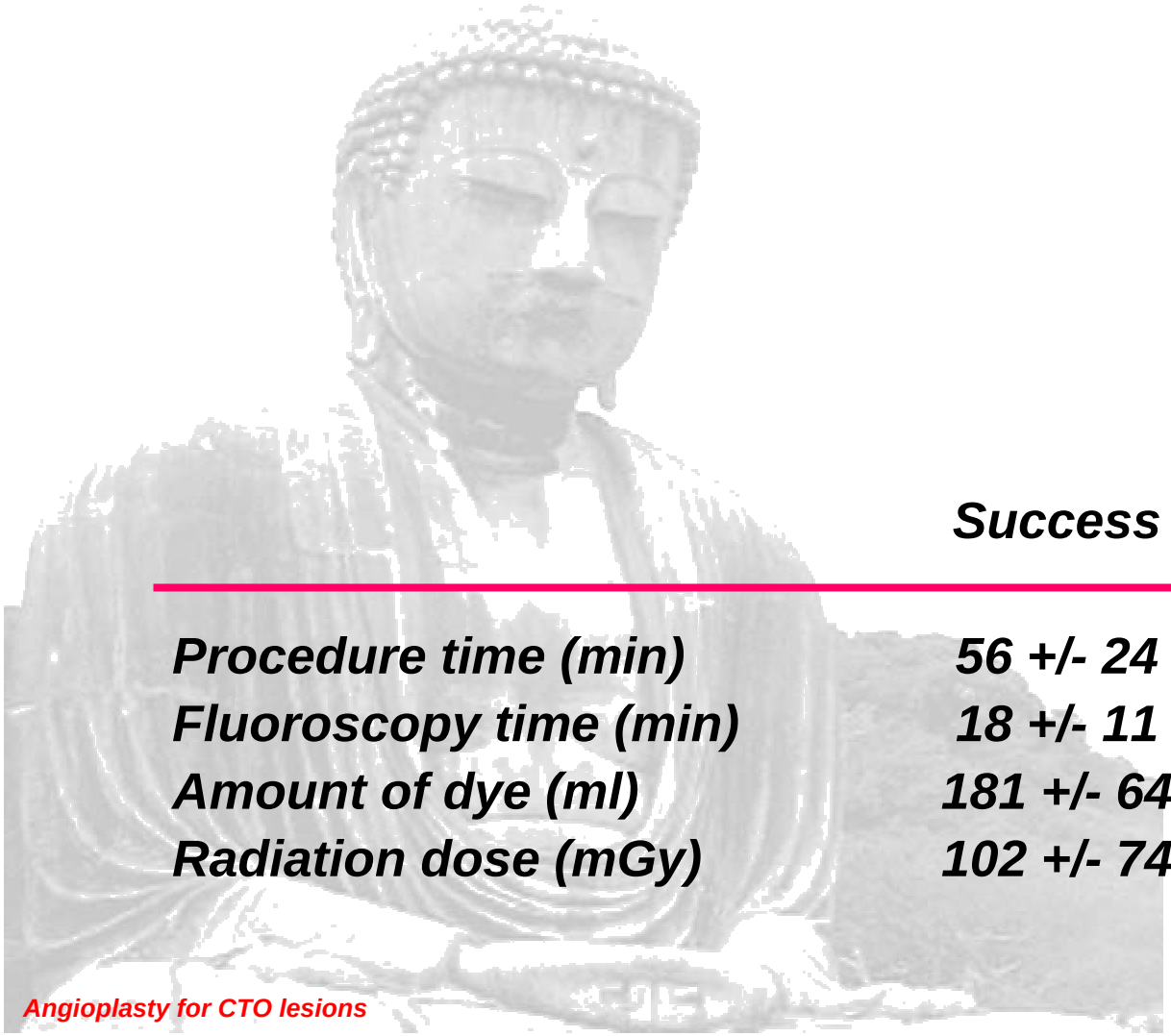
Kawakami T, et al. Chronic radiodermatitis following repeated percutaneous transluminal coronary angioplasty. Br J Dermatol 1999; 141: 150-3.

- **Case 1, 63 y.o. male:**
  - During 17 months of IHD histoy
    - 5 diagnostic CAGs + 3 PCIs for RCA lesion
  - Total radiation dose
    - 1,000 cGy
- **Case 2, 63 y.o. female:**
  - During 19 months of IHD history
    - 7 diagnostic CAGs + 6 PCIs for LAD lesion
  - Total radiation dose
    - 2,300 cGy
- **Case 3, 54 y.o. female:**
  - During 14 months of IHD history
    - 5 diagnostic CAGs + 2 PCIs for LAD lesion
  - Total radiation dose
    - 1,000 cGy

Methods

- **Lesion population:**
  - Total of 1,004 lesions, which were totally occluded and treated by elective PCI in ShonanKamakura General Hospital between 1997 and February 2003.
    - Procedure time:
      - 57 +/ 24 minutes
    - Fluoroscopy time:
      - 20 +/- 19 minutes
    - Amount of dye:
      - 153 +/- 173 ml
    - Radiation dose:
      - 99 +/- 101 mGy

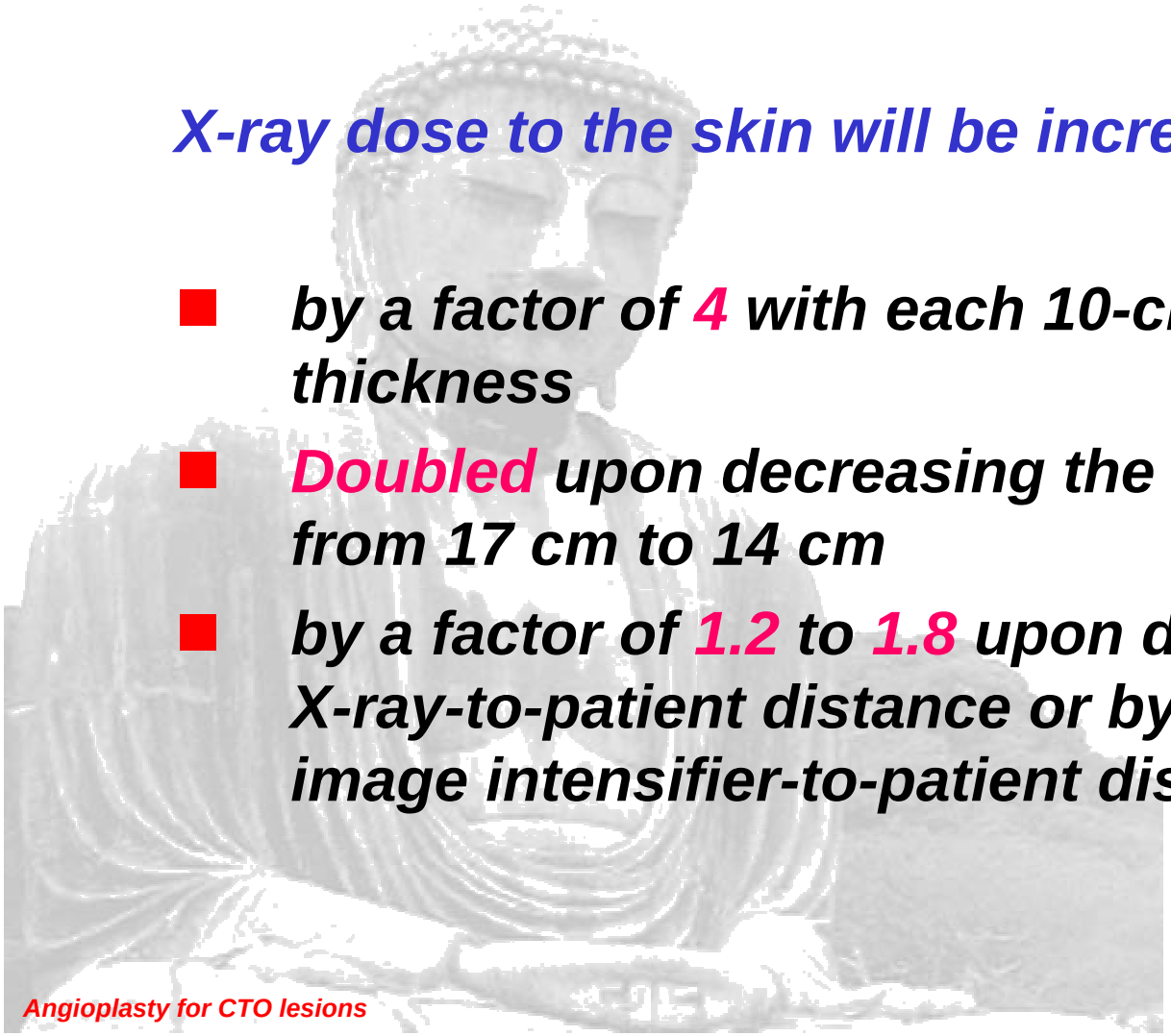
Comparisons between lesion with and without PCI success



	Success	*Failed*	*p*
Procedure time (min)	*56 +/- 24*	*45 +/- 26*	*0.843*
Fluoroscopy time (min)	*18 +/- 11*	*20 +/- 10*	*0.220*
Amount of dye (ml)	*181 +/- 64*	*153 +/- 71*	*0.010*
Radiation dose (mGy)	*102 +/- 74*	*99 +/- 63*	*0.856*

X-ray dose to the skin during PCI

Miralbell R, et al. X-ray dose to the skin in patients undergoing percutaneous transluminal coronary angioplasty. Catheter Cardiovasc Interv 2000; 50: 300-6.



X-ray dose to the skin will be increased------,

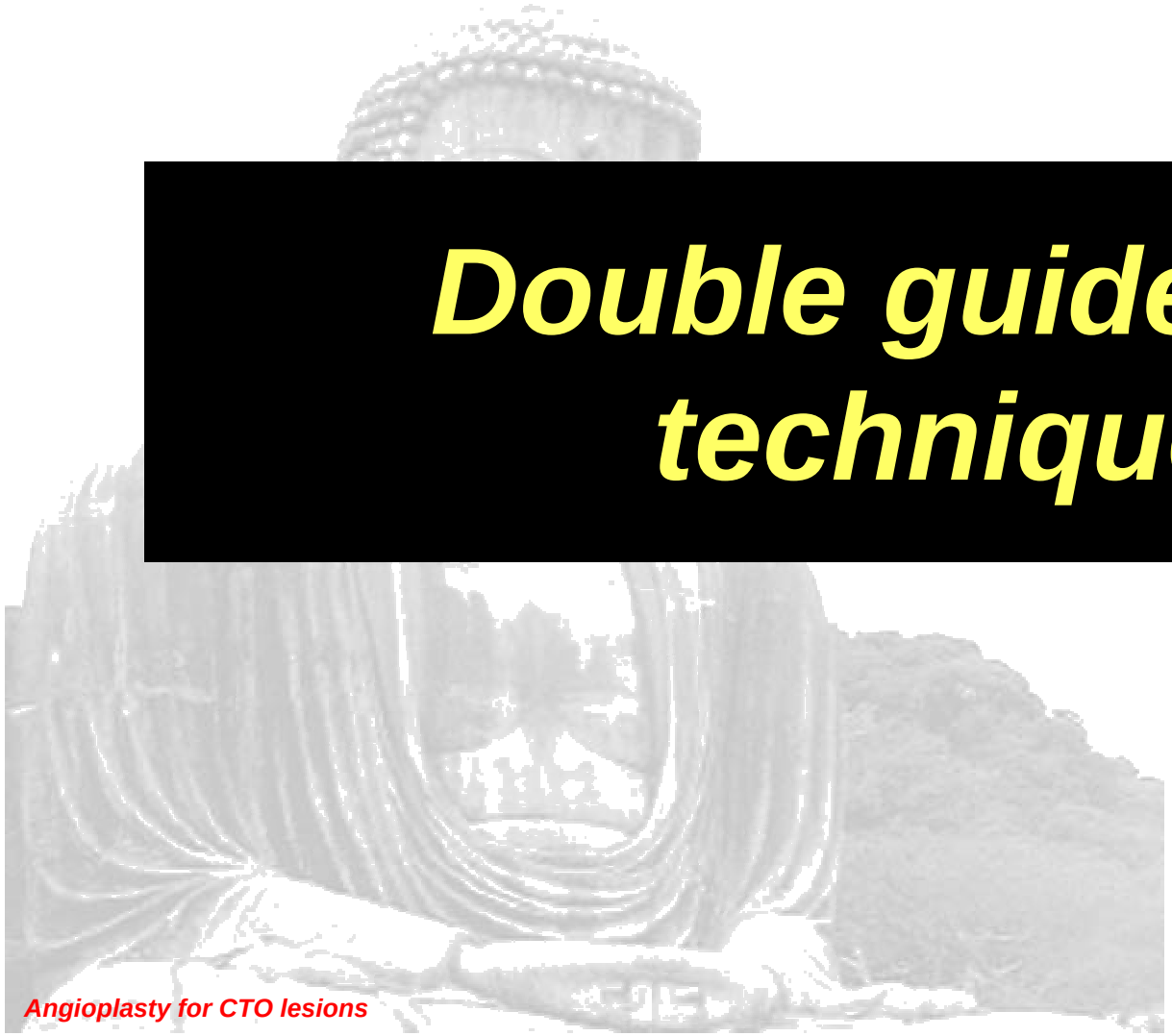
- ***by a factor of 4 with each 10-cm increment of thickness***
- ***Doubled upon decreasing the field diameter from 17 cm to 14 cm***
- ***by a factor of 1.2 to 1.8 upon decreasing the X-ray-to-patient distance or by increasing the image intensifier-to-patient distance***

How long we can continue the procedure for CTO lesions?

- My recommendation is:
  1. Time from the arterial access to the successful penetration of a guidewires through the occlusion should be <= 30 minutes.
  2. Total procedure time should be <= 90 minutes
  3. Total dye volume should be <= 300 ml.

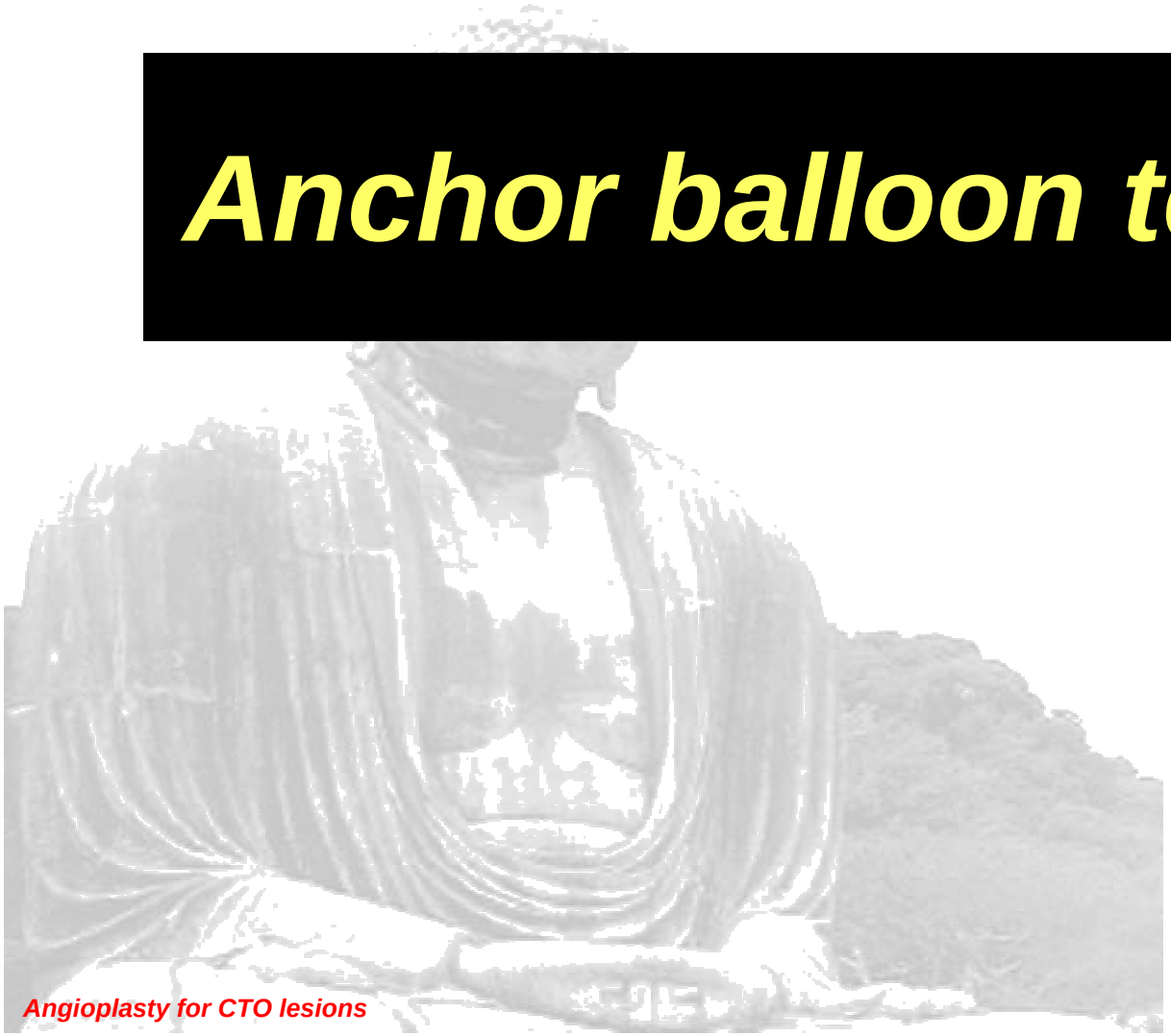
If we reach at one of the above points, we should quit the procedure irrespective of the results.

Special Tips in PCI for CTO lesions



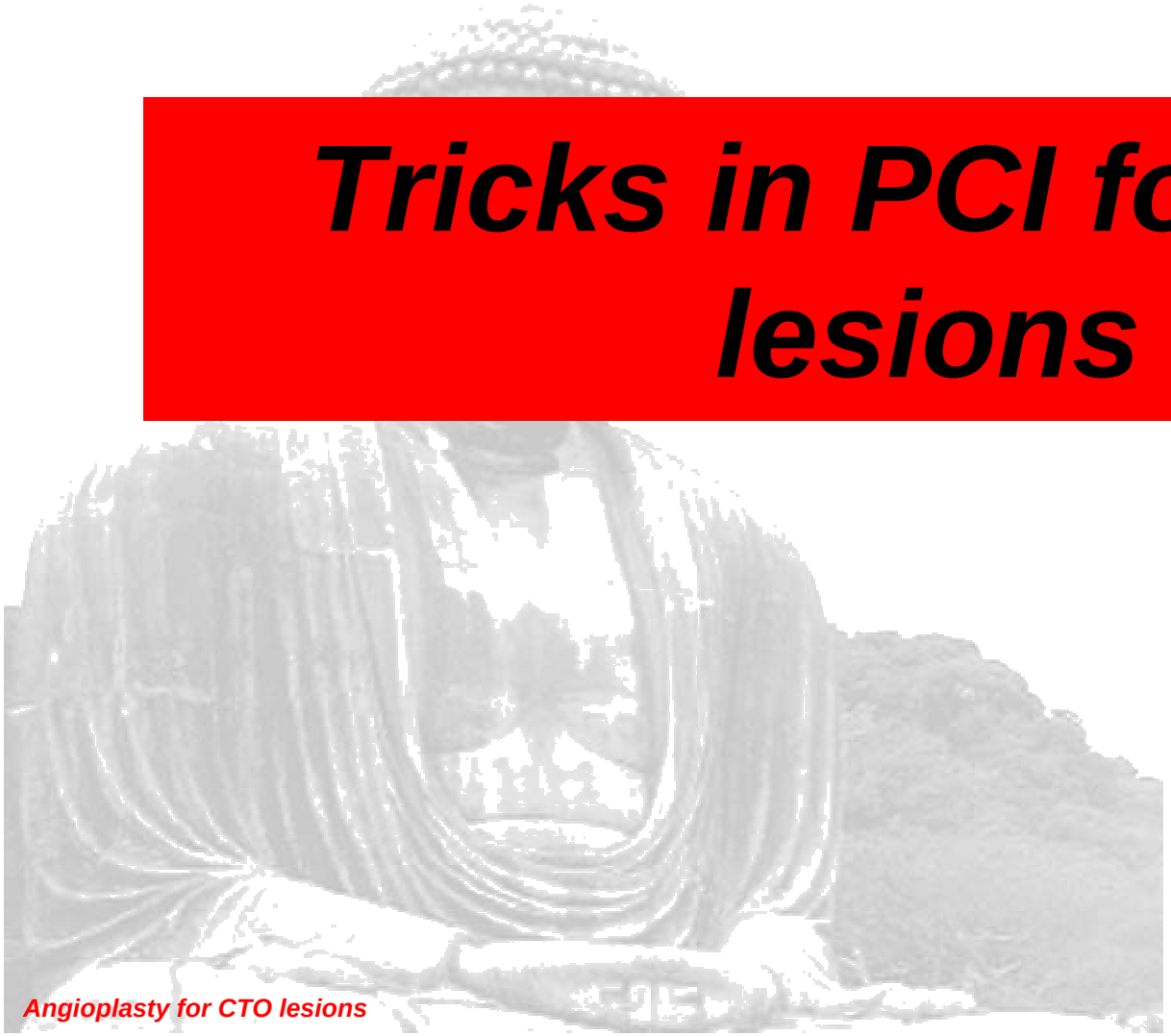
Double guidewire technique

Anchor balloon technique



Mother-and-Child guiding catheter technique (Saito's Technique)

Tricks in PCI for CTO lesions



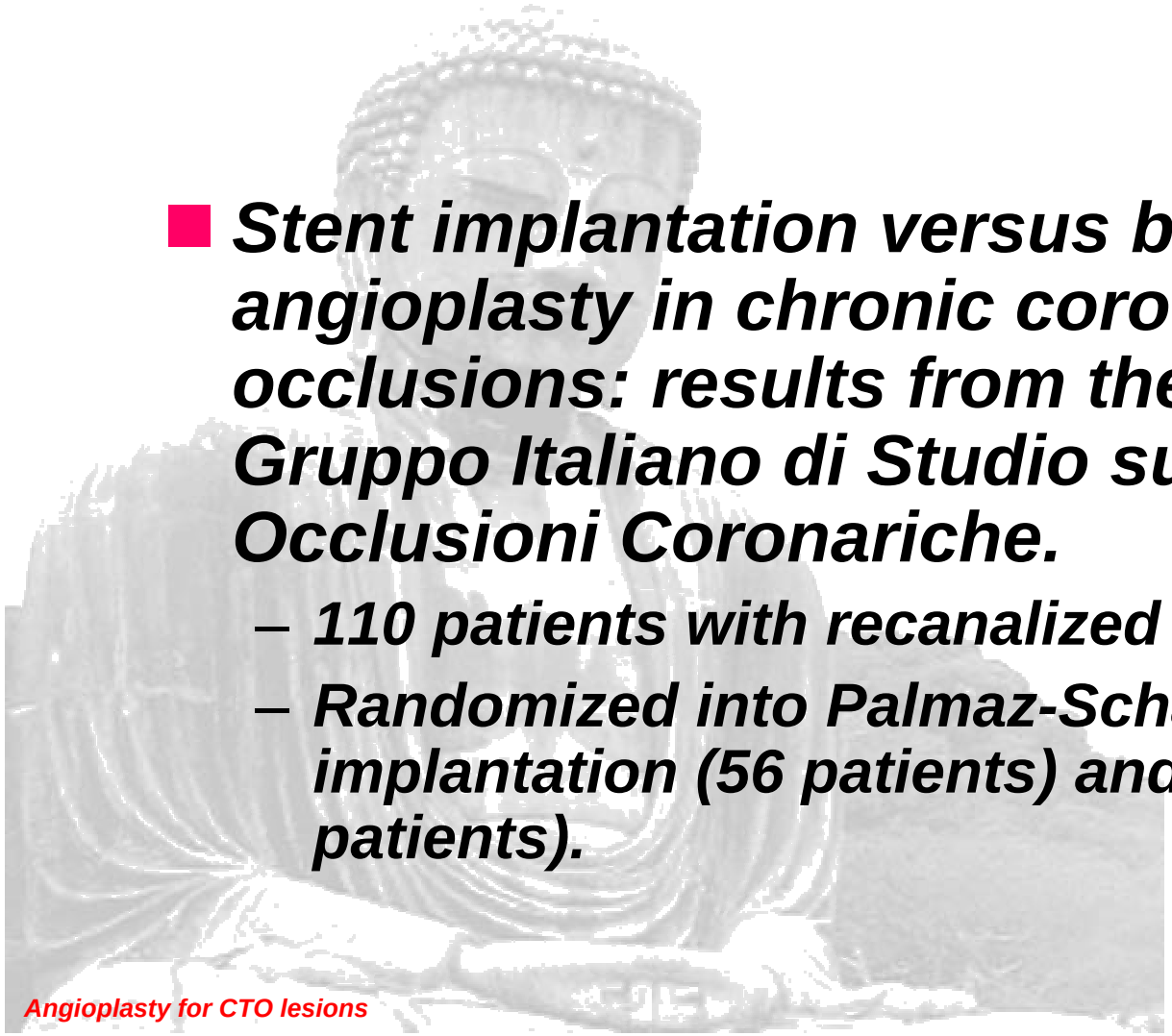
Unusual tortuosity after bypass surgery

Do not trust on the gap between a guidewire and distal contrast filling

Stent implantation for CTO lesions

Importance of Stent Implantation after Successful PCI for CTO

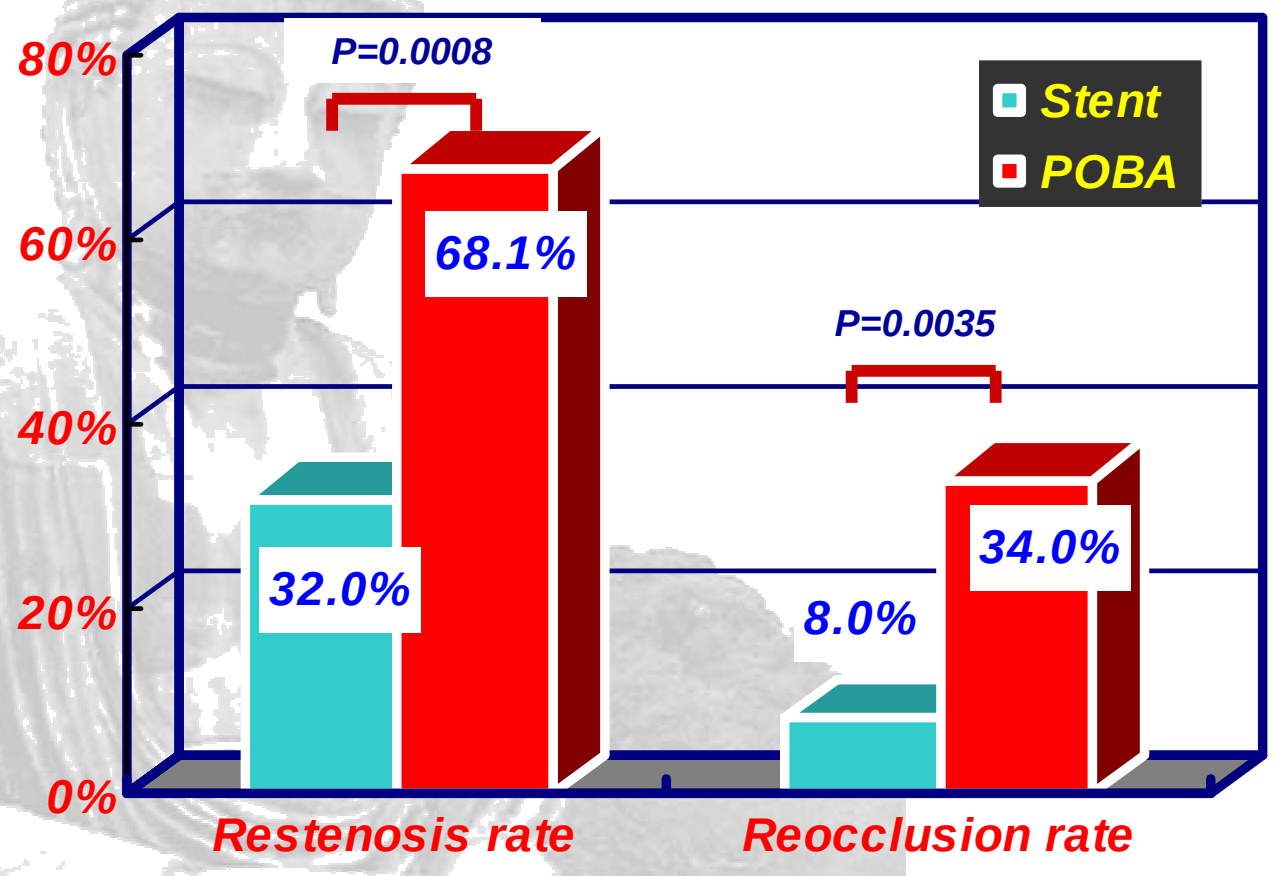
Rubartelli P, et al. Stent implantation versus balloon angioplasty in chronic coronary occlusions: results from the GISSOC trial. Gruppo Italiano di Studio sullo Stent nelle Occlusioni Coronariche.J Am Coll Cardiol 1998; 32: 90-6.



- ***Stent implantation versus balloon angioplasty in chronic coronary occlusions: results from the GISSOC trial. Gruppo Italiano di Studio sullo Stent nelle Occlusioni Coronariche.***
  - *110 patients with recanalized CTO lesions*
  - *Randomized into Palmaz-Schatz stent implantation (56 patients) and POBA (54 patients).*

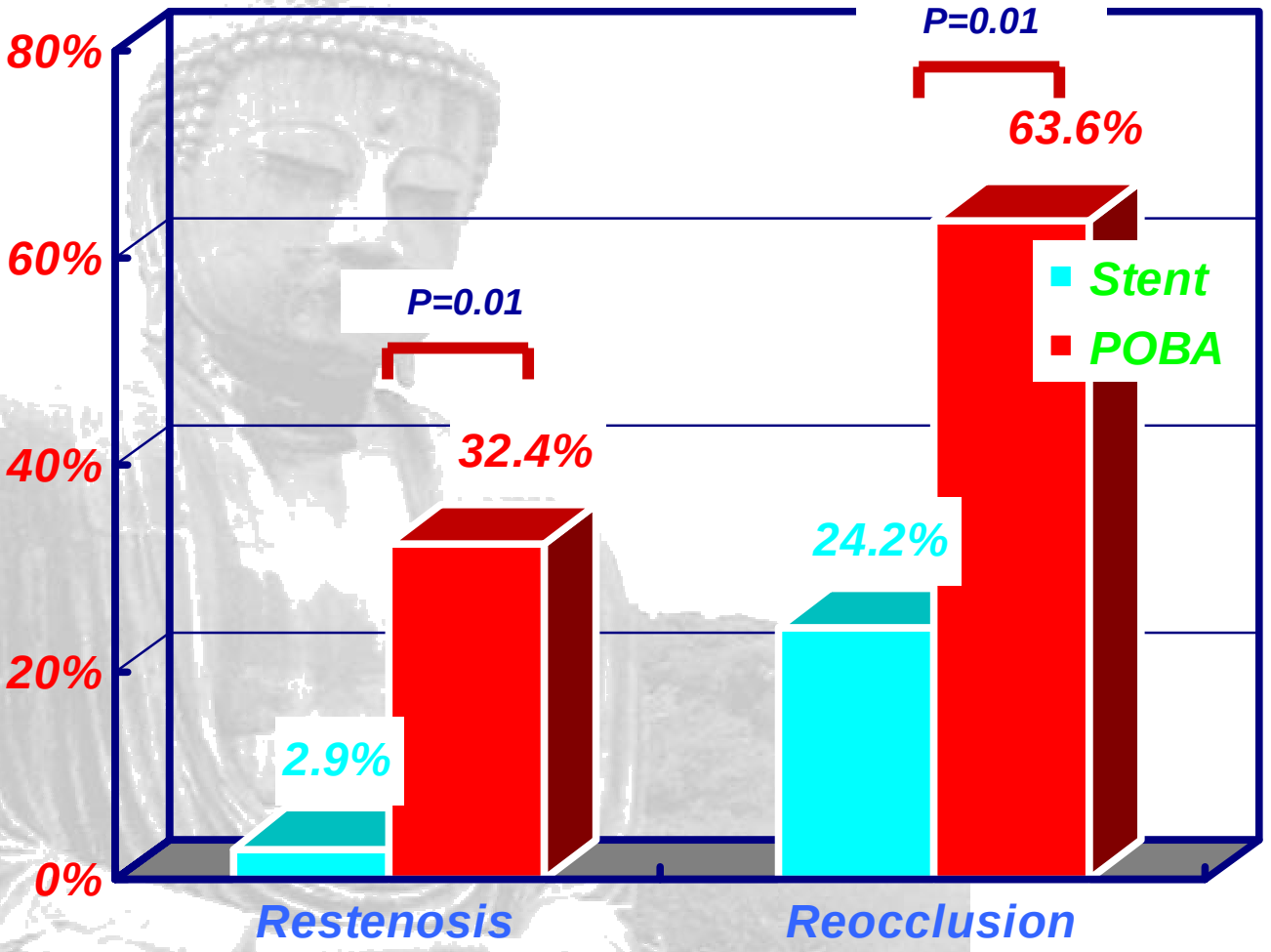
Importance of Stent Implantation after Successful PCI for CTO

Rubartelli P, et al. Stent implantation versus balloon angioplasty in chronic coronary occlusions: results from the GISSOC trial. Gruppo Italiano di Studio sullo Stent nelle Occlusioni Coronariche.J Am Coll Cardiol 1998; 32: 90-6.



Importance of Stent Implantation after Successful PCI for CTO – SPACTO Trial

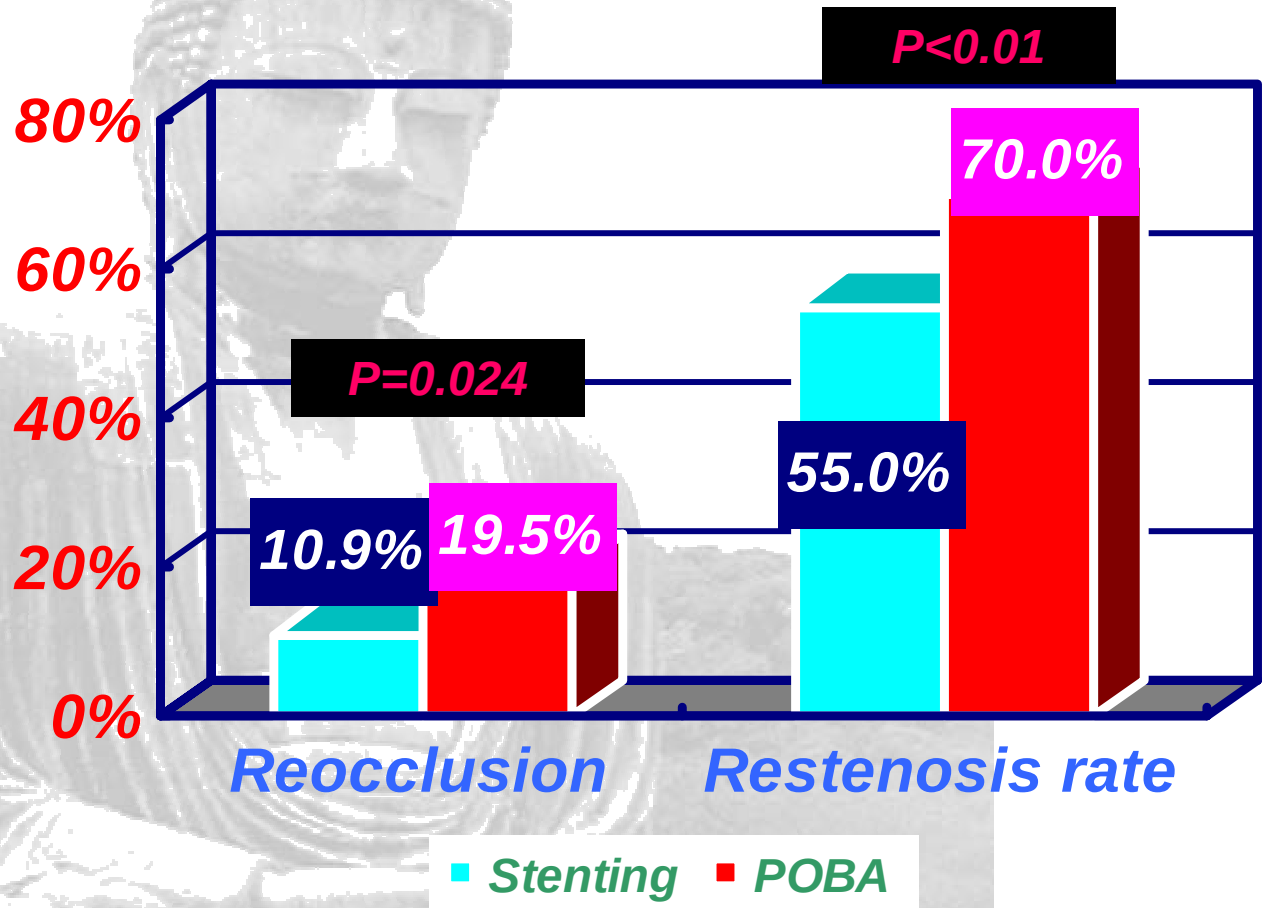
Hoher M, et al. A randomized trial of elective stenting after balloon recanalization of chronic total occlusions.J Am Coll Cardiol 1999; 34: 722-9.



Stent implantation can improve the patency of CTO lesions after successful recanalization

Buller CE, et al. Primary stenting versus balloon angioplasty in occluded coronary arteries: the Total Occlusion Study of Canada (TOSCA). Circulation 1999; 100: 236-42.

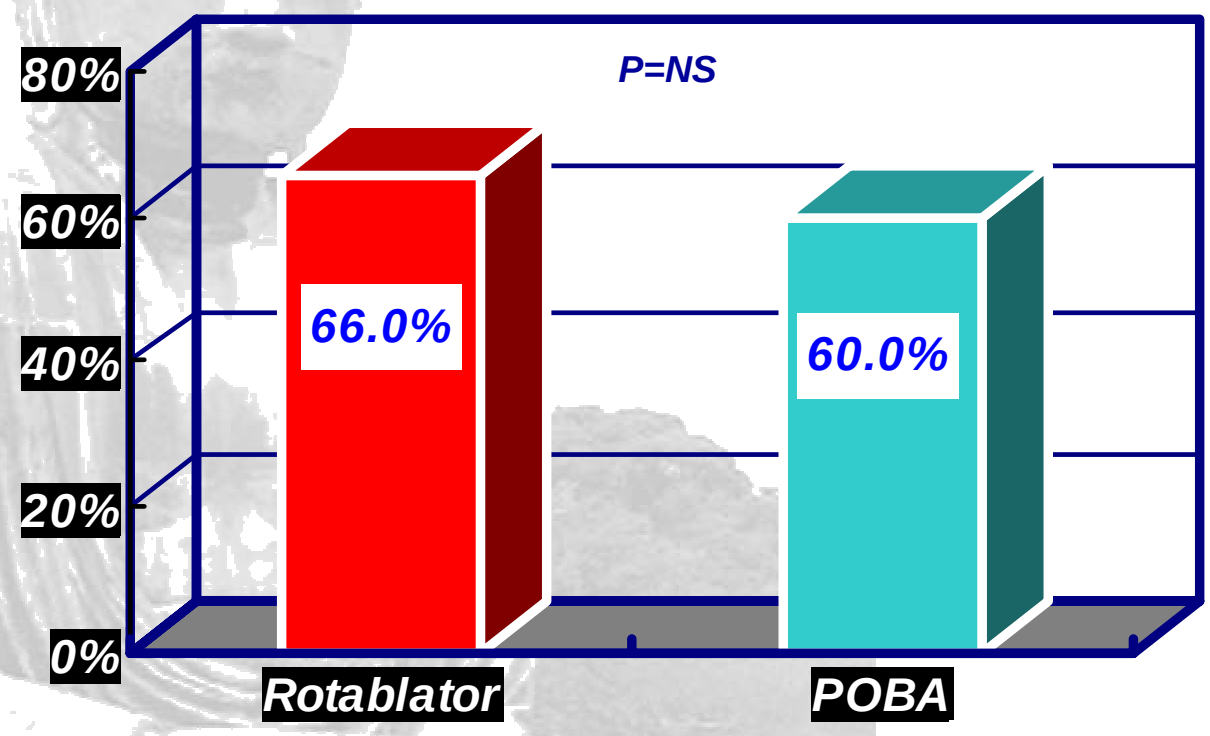
Reocclusion and binary restenosis rates after successful recanalization of CTO lesions



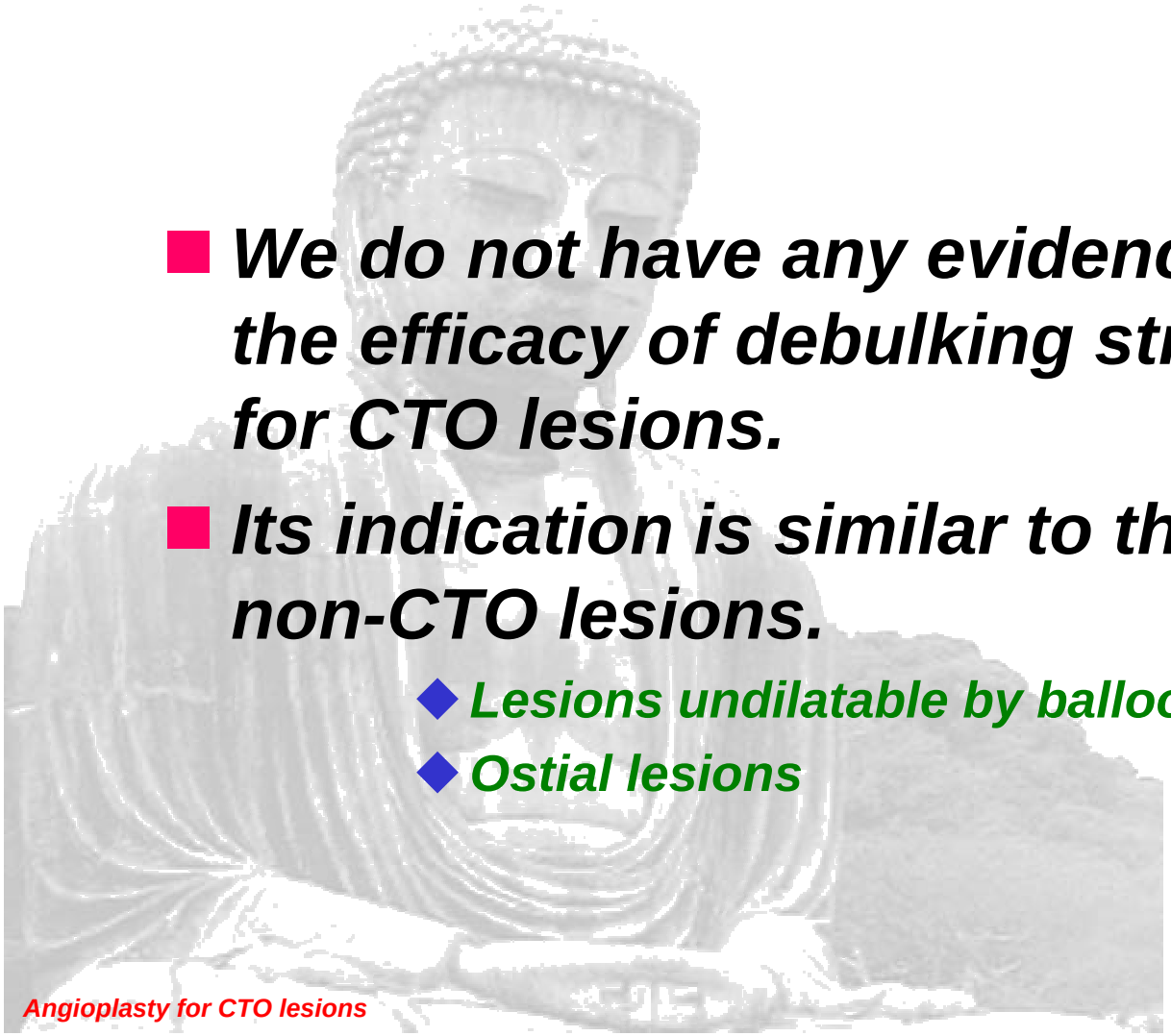
Debulking strategy for CTO lesions

Rotablator is not superior to POBA in PCI for CTO lesions

Danchin N, et al. Balloon angioplasty versus rotational angioplasty in chronic coronary occlusions (the BAROCCO study). Am J Cardiol 1995; 75: 330-4.



Debulking strategy for CTO lesions



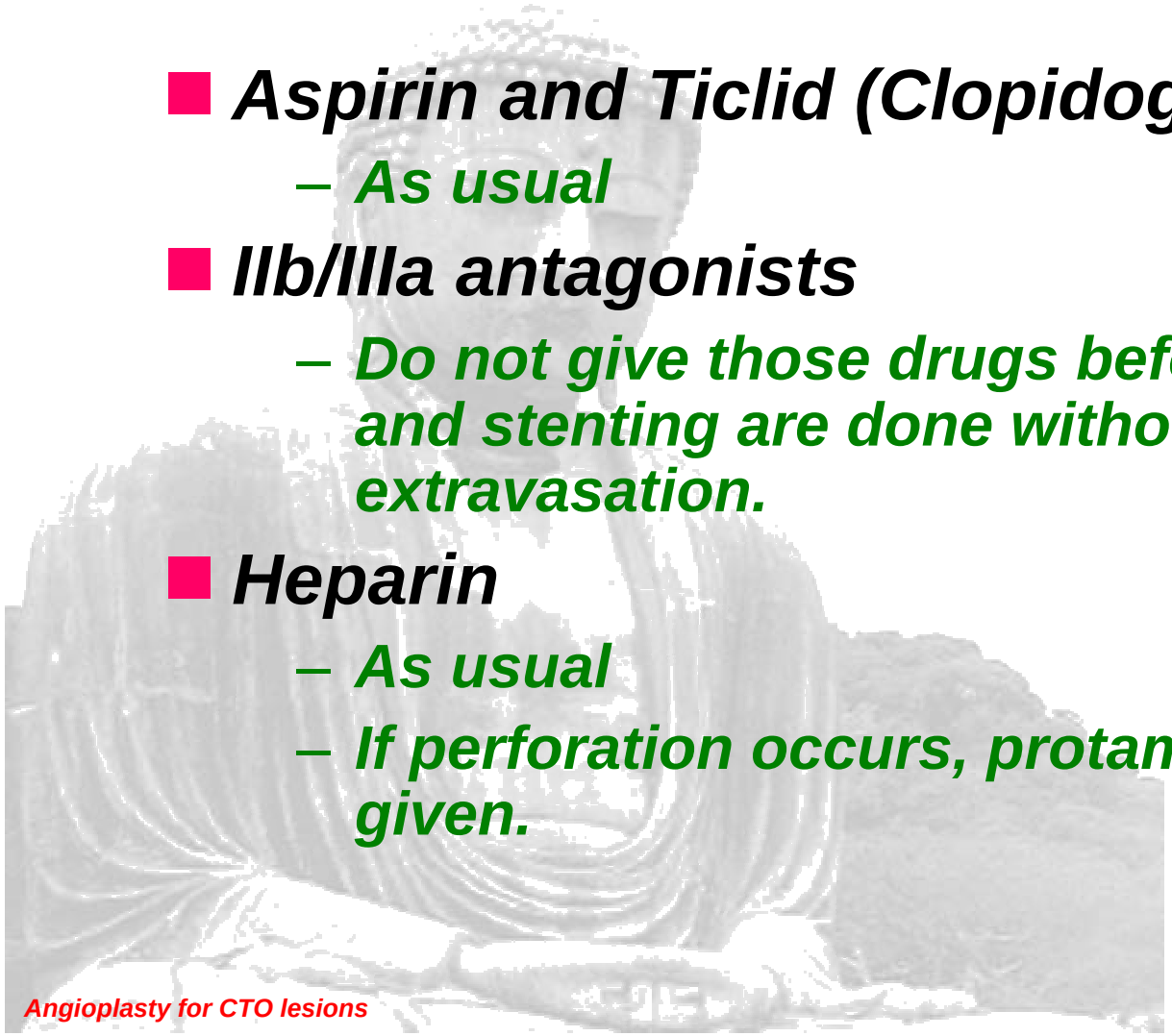
- ***We do not have any evidence that proves the efficacy of debulking strategy in PCI for CTO lesions.***
- ***Its indication is similar to that in PCI for non-CTO lesions.***
  - ***Lesions undilatable by balloons***
  - ***Ostial lesions***

Complications during PCI for CTO lesions

Complications during PCI for CTO lesions

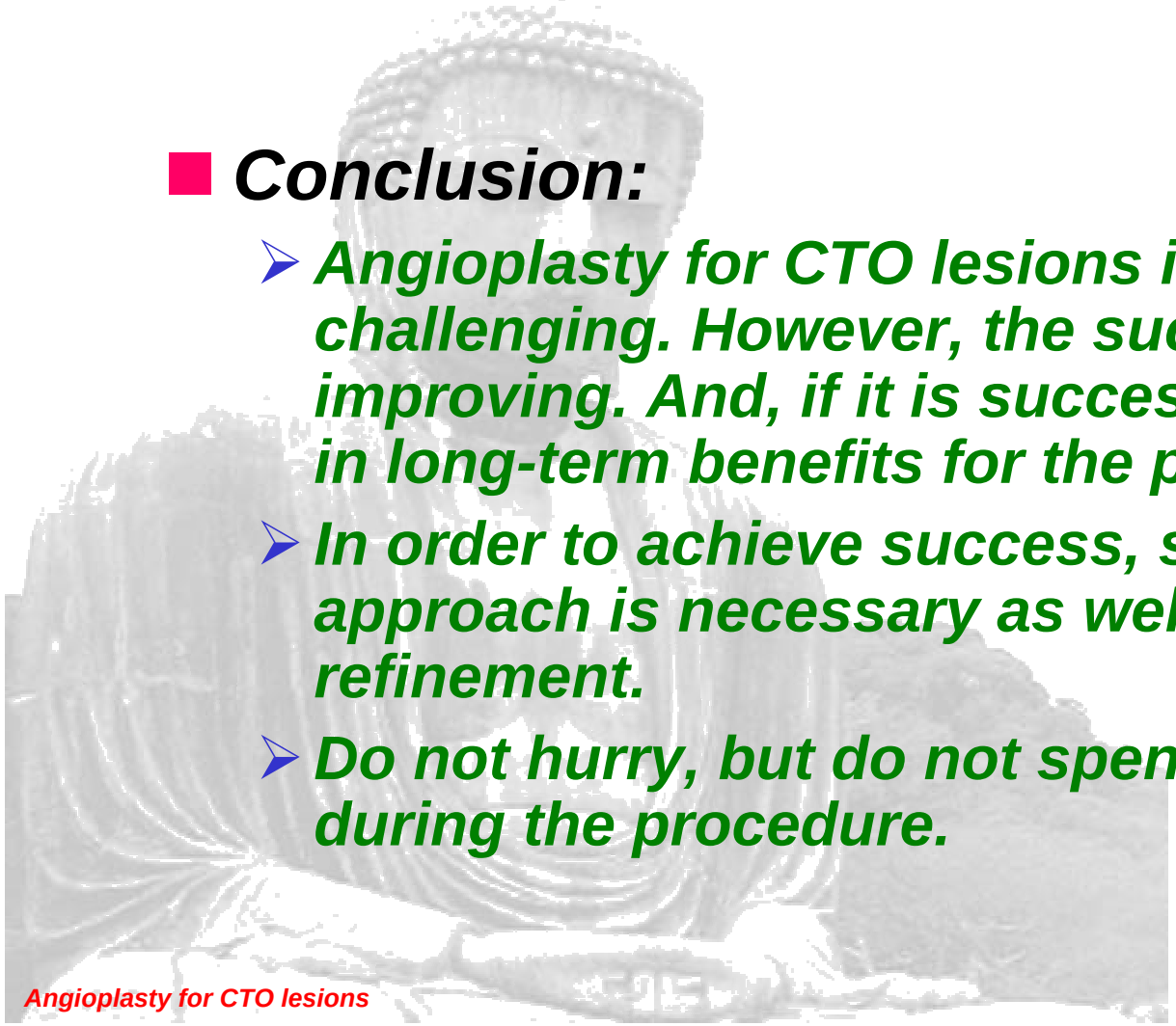
- *Uncommon*
  - *> diagnostic CAG but < PCI for non-CTO lesions*
- *QMI (~1%)*
  - *Due to reocclusion or damage to the collateral feeding, or due to extensive dissection*
- *Urgent CABG (~1%)*
- *Coronary perforation/rupture (~2%)*
  - *The incidence depends on which guidewires are used*
- *Cardiac tamponade*
  - *Pericardiocenthesis is enough*
- *Dissection of coronary arteries (~2%)*
  - *More common in RCA*
- *Distal slow flow/no reflow*
  - *Depending on whether the lesion contains clot or not*

Special concern for medication before and during PCI for CTO lesions



- ***Aspirin and Ticlid (Clopidogrel)***
  - ***As usual***
- ***IIb/IIIa antagonists***
  - ***Do not give those drugs before ballooning and stenting are done without any signs of extravasation.***
- ***Heparin***
  - ***As usual***
  - ***If perforation occurs, protamine should be given.***

Angioplasty for CTO lesions



- **Conclusion:**
  - Angioplasty for CTO lesions is still technically challenging. However, the success rate is improving. And, if it is successful, it will result in long-term benefits for the patients.
  - In order to achieve success, strategic approach is necessary as well as technical refinement.
  - Do not hurry, but do not spend too long time during the procedure.