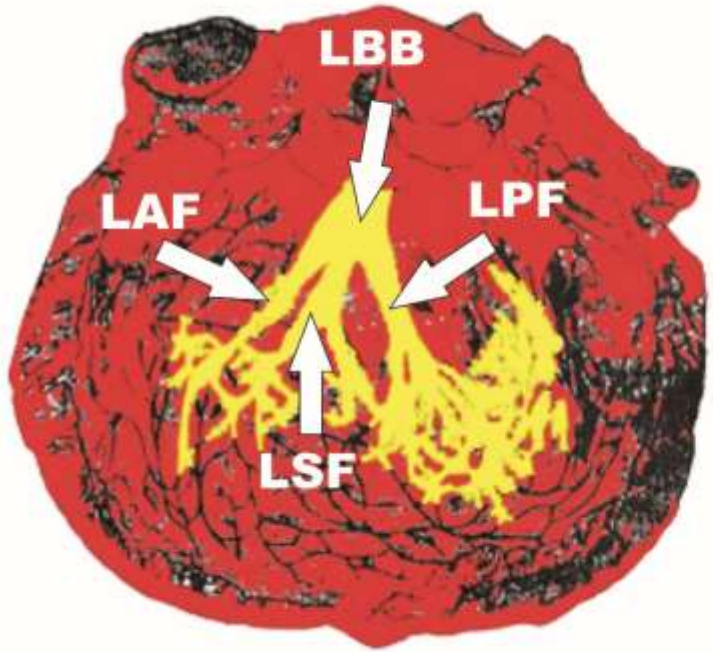
The Sunao Tawara concept

At the beginning of the 20th Century, Dr. Sunao Tawara (1906) clearly showed that anatomically, the trunk of the LBB splits into three fascicles (**Tawara 1906-1906**).

Tawara's pioneering work on the conduction system: "The Conduction System of the Mammalian Heart" (1906), still serves as an invaluable reference for basic and clinical research. Figure 1

Sunao Tawara studied at the Imperial University in Tokyo, graduating there in 1901, Igaku Hakushi 1908. The years 1903 to 1906 he spent in Marburg studying pathology and pathological anatomy with Karl Albert Ludwig Aschoff (1866-1942). It was here he undertook his important works on the anatomy and pathology of the heart. When returning to Japan he was appointed extraordinary professor of pathology in Fukuoka, becoming *ordinarius* of this specialty in 1908.

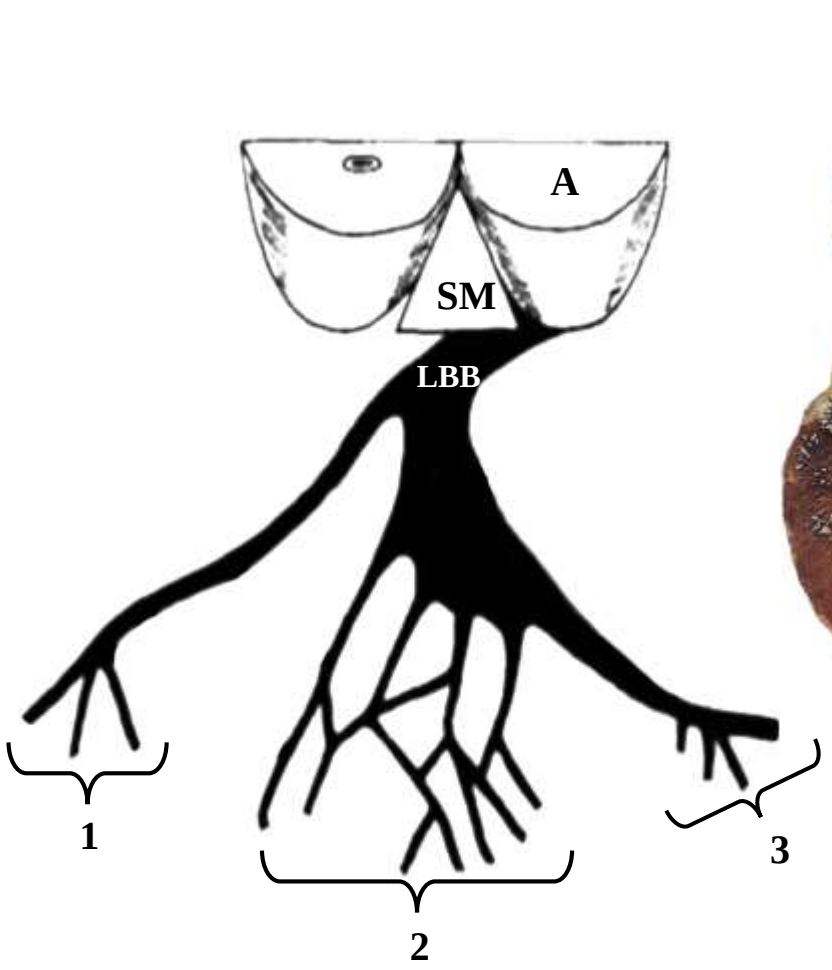
The trifascicular nature of the left His system following Tawara's concept

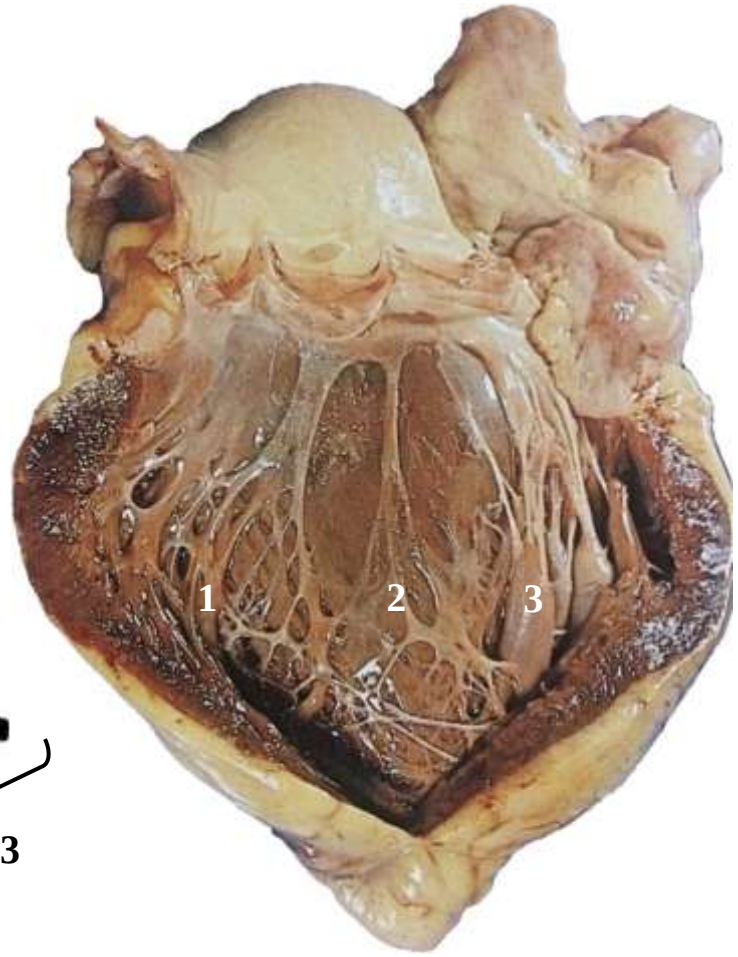


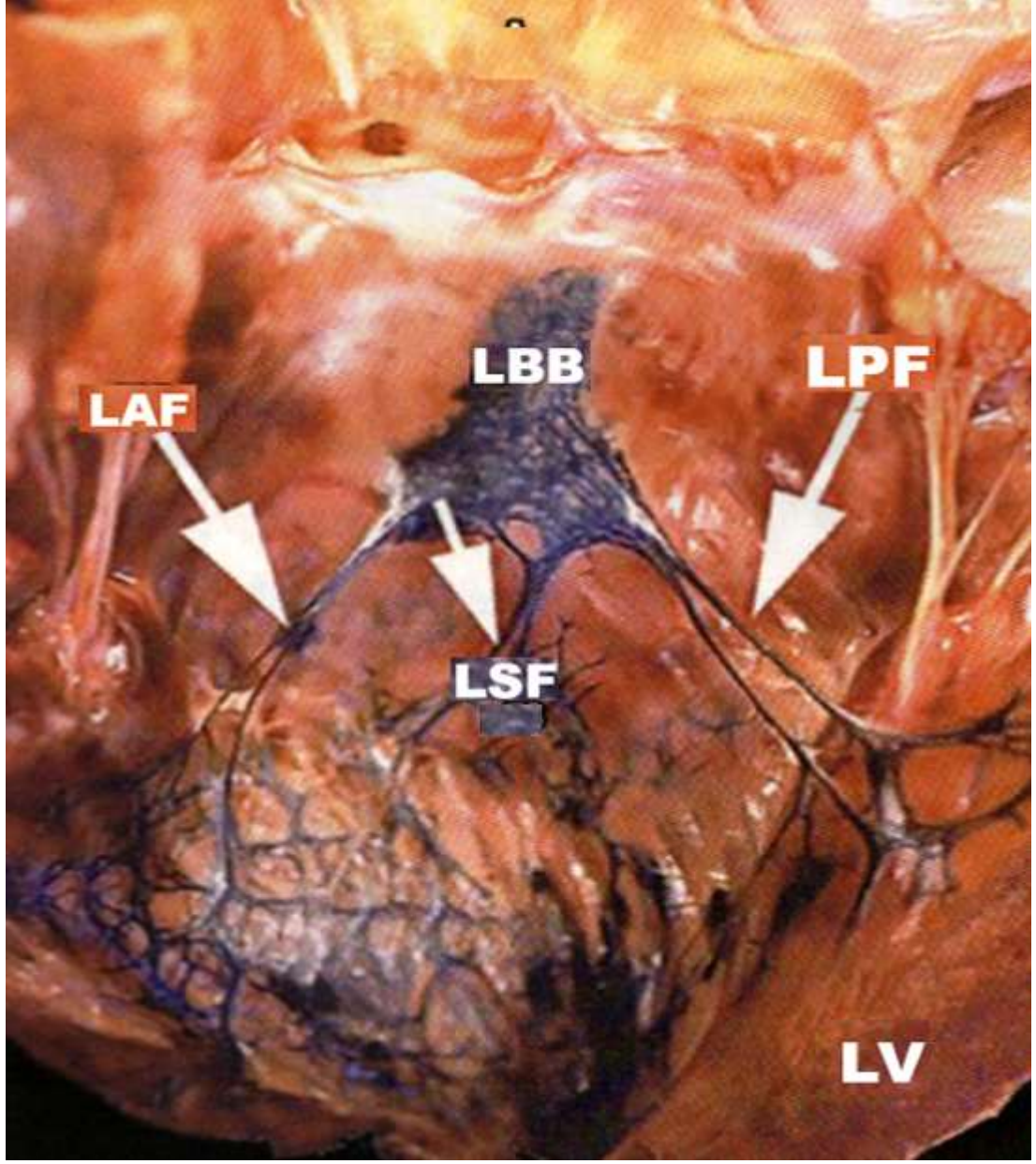
LBB: Left Bundle Branch
LAF: Left Anterior Fascicle
LPF: Left Posterior Fascicle
LSF: Left Septal Fascicle

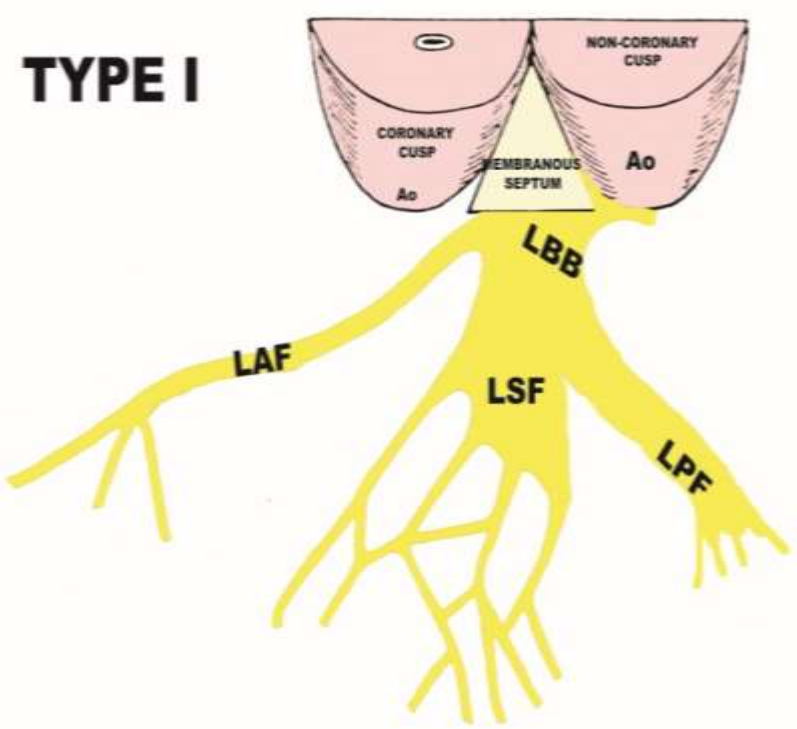
Sunao Tawara (July 5, 1873 – January 19, 1952)

The trunk of the left bundle branch (LBB) of the His bundle split in three fascicles: Left Anterior Fascicle (LAF), Left Septal Fascicle (LSF) and Left Posterior Fascicle (LPF).

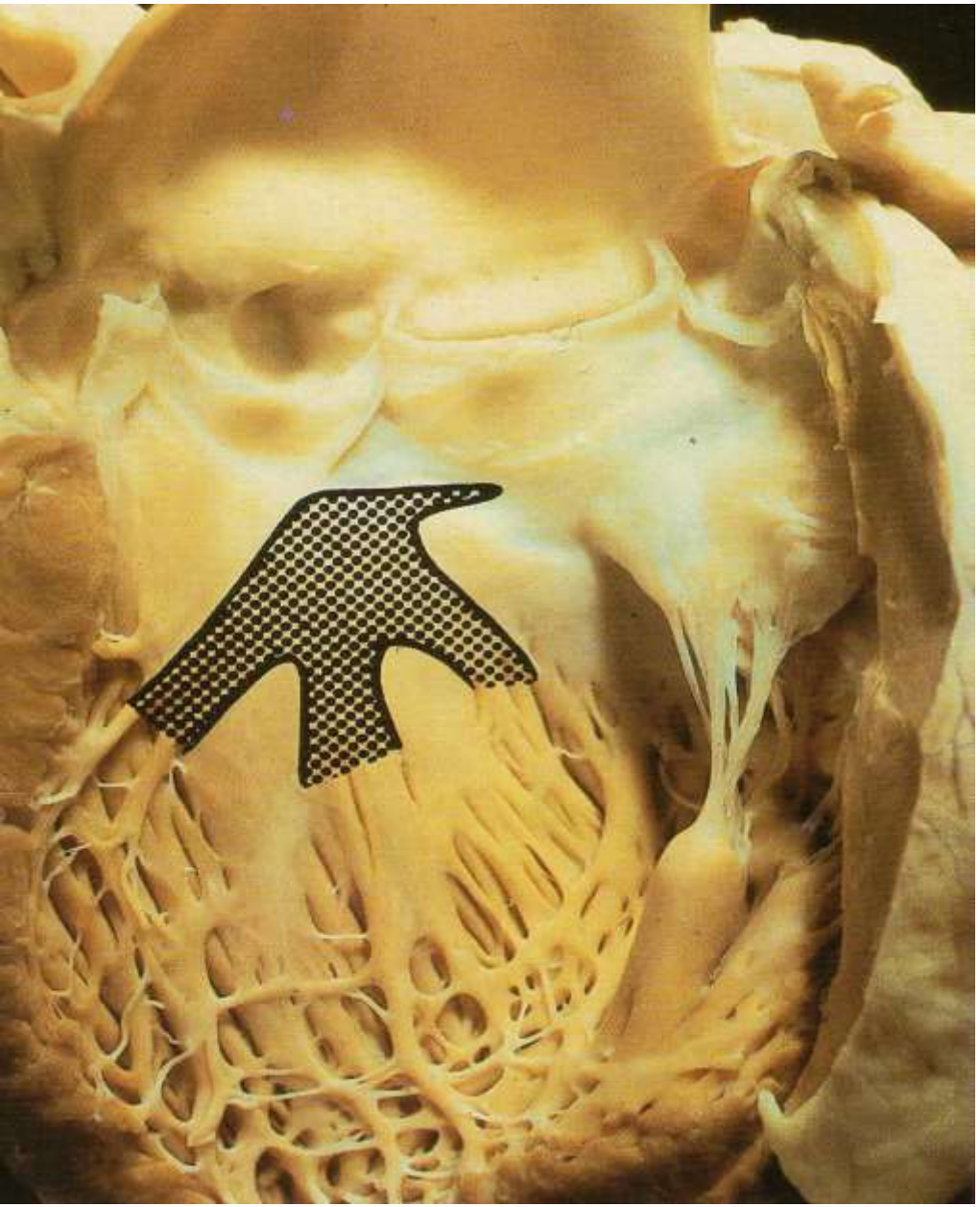

A
SM
LBB
1
2
3

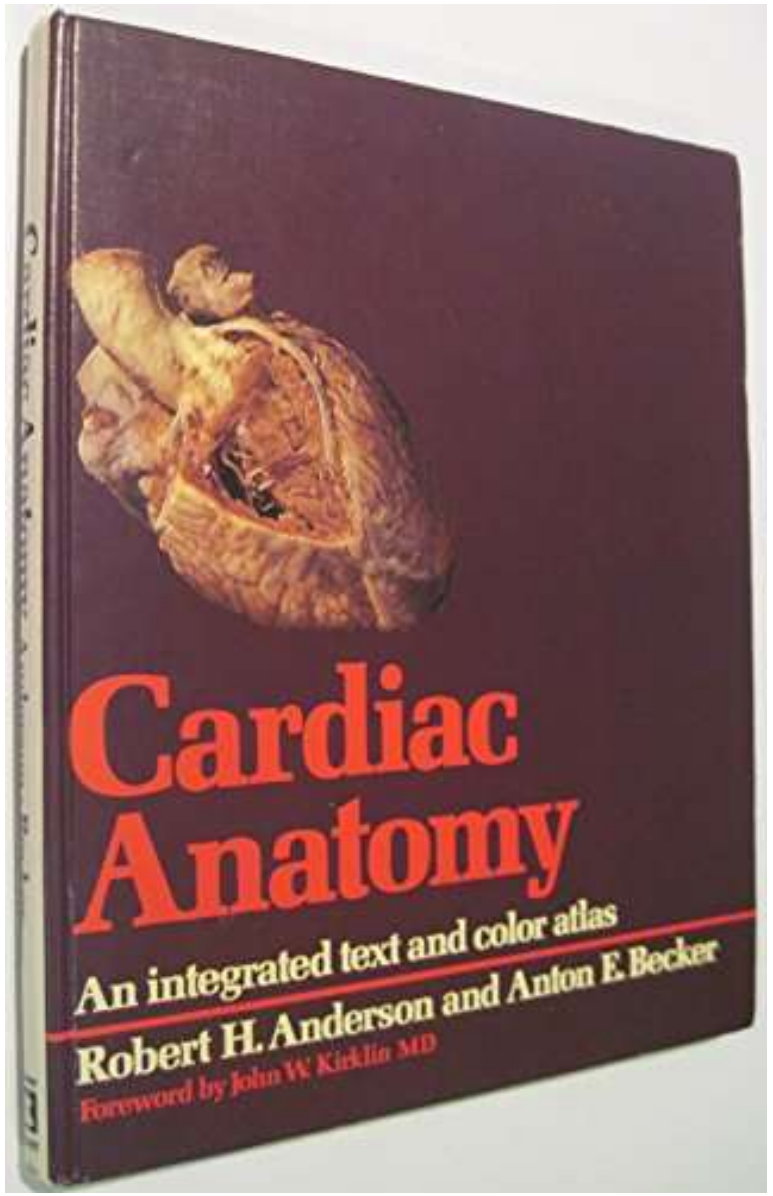

1
2
3





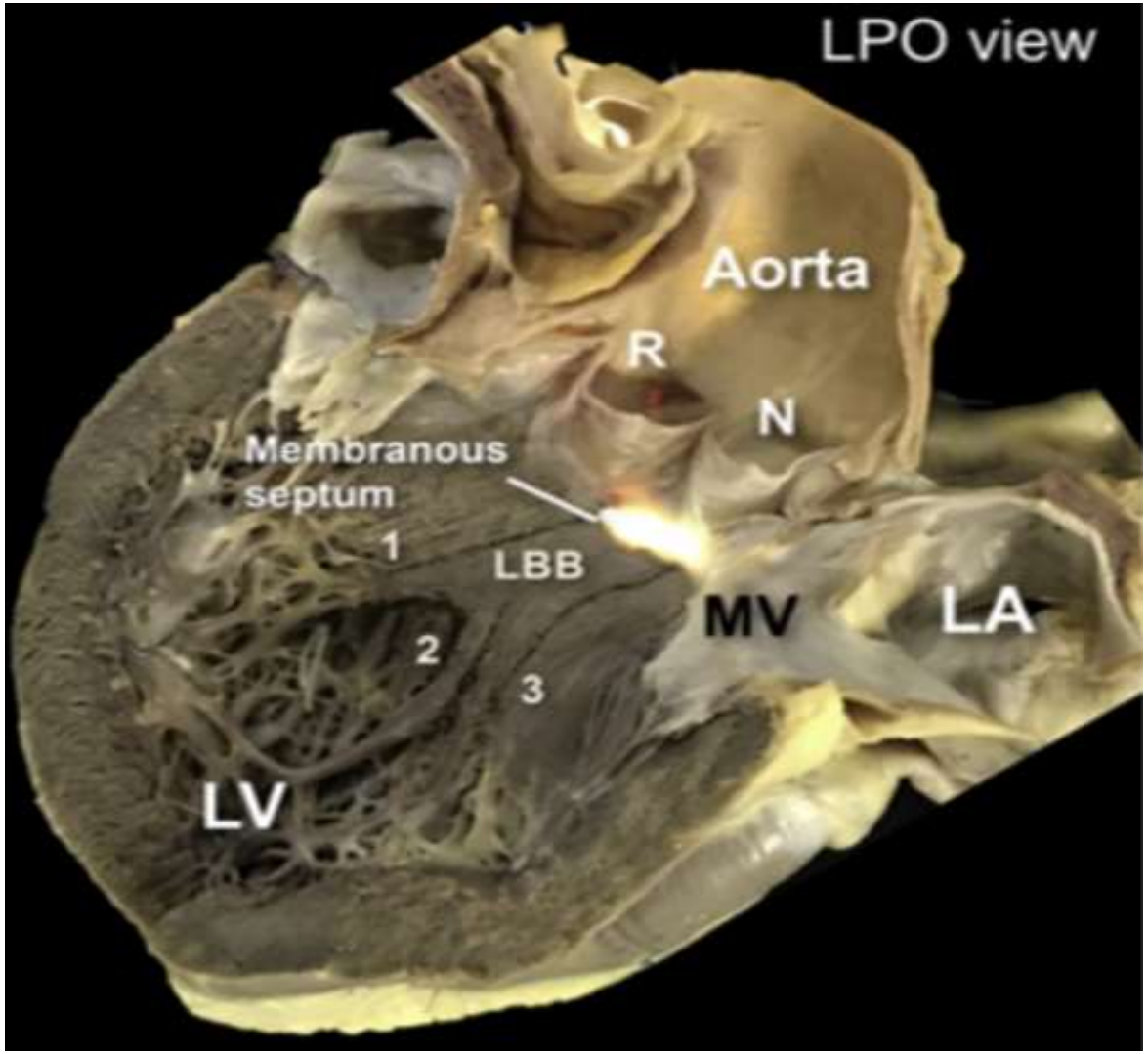
Anatomical piece of a human heart showing the endocardial septal surface of the Left Ventricle(LV) with the left bundle branch (LBB) and its three divisions or fascicles: Left Anterior Fascicle (LAF), Left Septal Fascicle (LSF), and Left Posterior Fascicle(LPF).





Robert H. Anderson
Retired clinical cardiac anatomist, but still involved in research and teaching.

Macroscopic View From a Human Postmortem Heart in Simulated LPO View



.José-Ángel Cabrera, Andreu Porta-Sánchez, Roderick Tung, Damián Sánchez-Quintana. Tracking Down the Anatomy of the Left Bundle Branch to Optimize Left Bundle Q1 Branch Pacing. JACC: Case Reports Volume 2, Issue 5, May 2020

DOI: 10.1016/j.jaccas.2020.04.004

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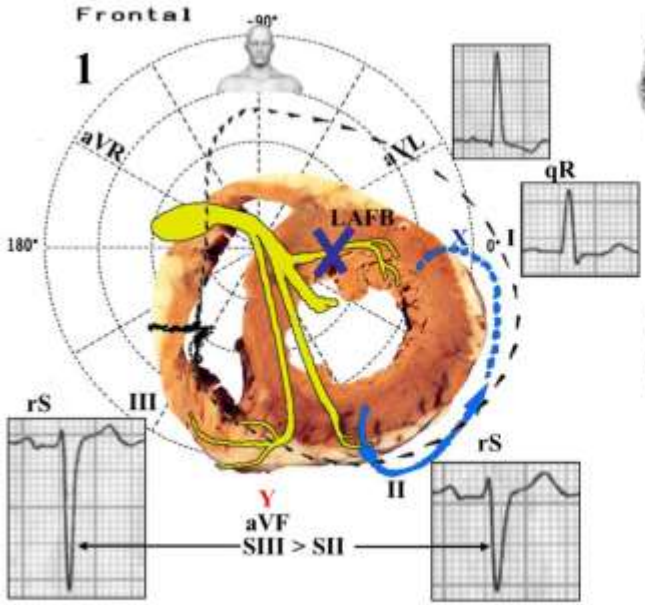
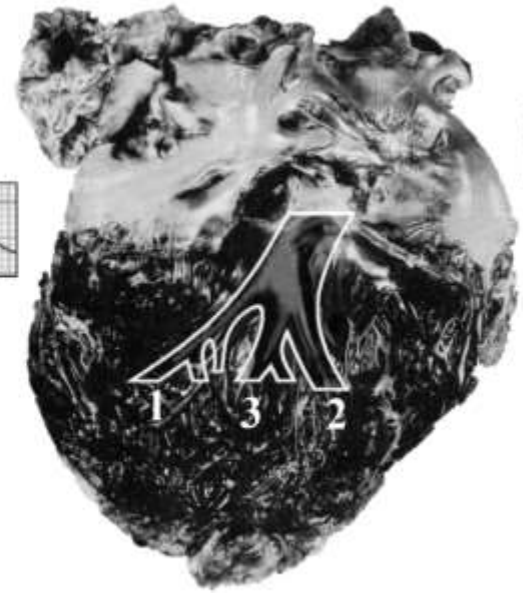
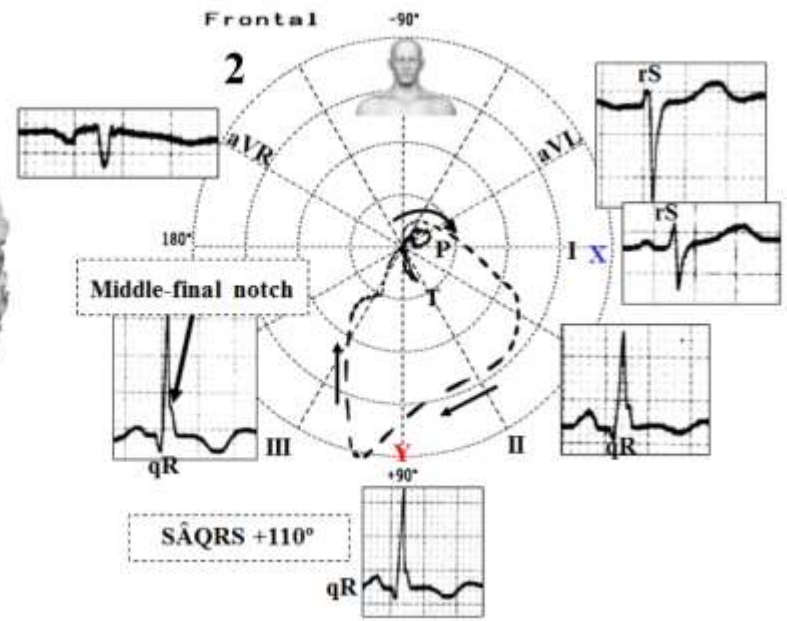
The Left Posterior oblique projection. (LPO) view shows the transilluminated membranous septum located inferior to the interleaflet triangle between the right (R) and noncoronary (N) sinus of the aortic valve. ,Note that we have highlighted in dark color the limits of the endocardial position of the left bundle branch (LBB) of His and its 3 fascicles, the left anterior (1), the left septal or middle (2), and the left posterior (3). LPO ¼ left posterior oblique; RAO ¼ right anterior oblique


Frontal
-90°
1
aVR
aVL
180°
0°
I
LAFB
qR
rS
III
rS
II
Y
aVF
SIII > SII


1
3
2


Frontal
-90°
2
aVR
aVL
rS
rS
180°
I X
P
T
Middle-final notch
qR
III
II
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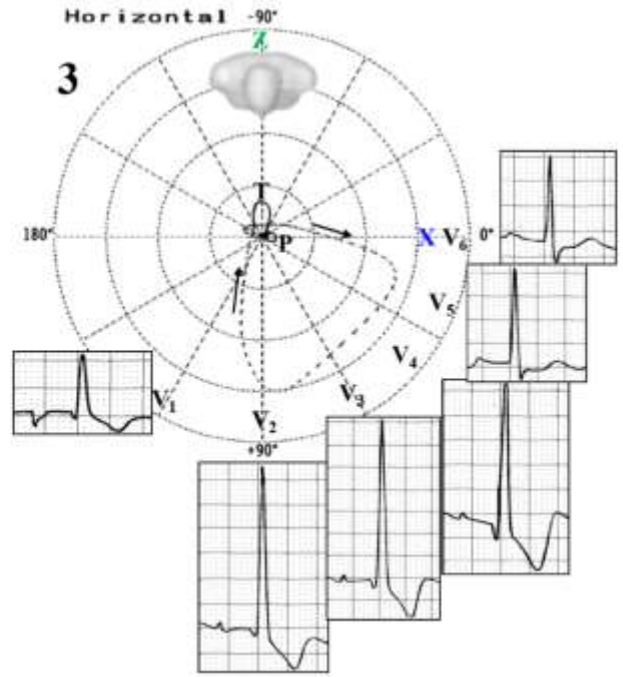
qR


Horizontal
-90°
Z
3
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V6
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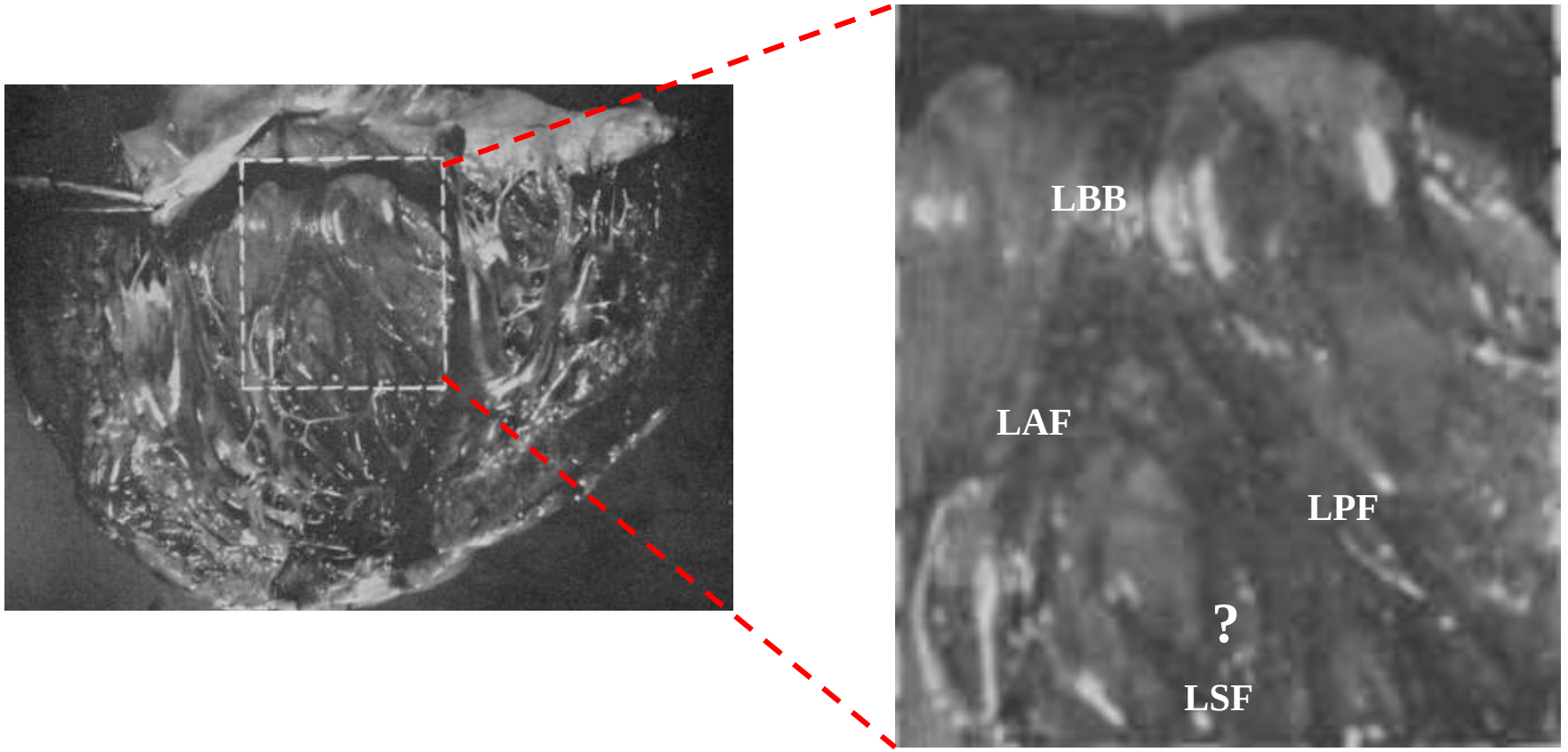
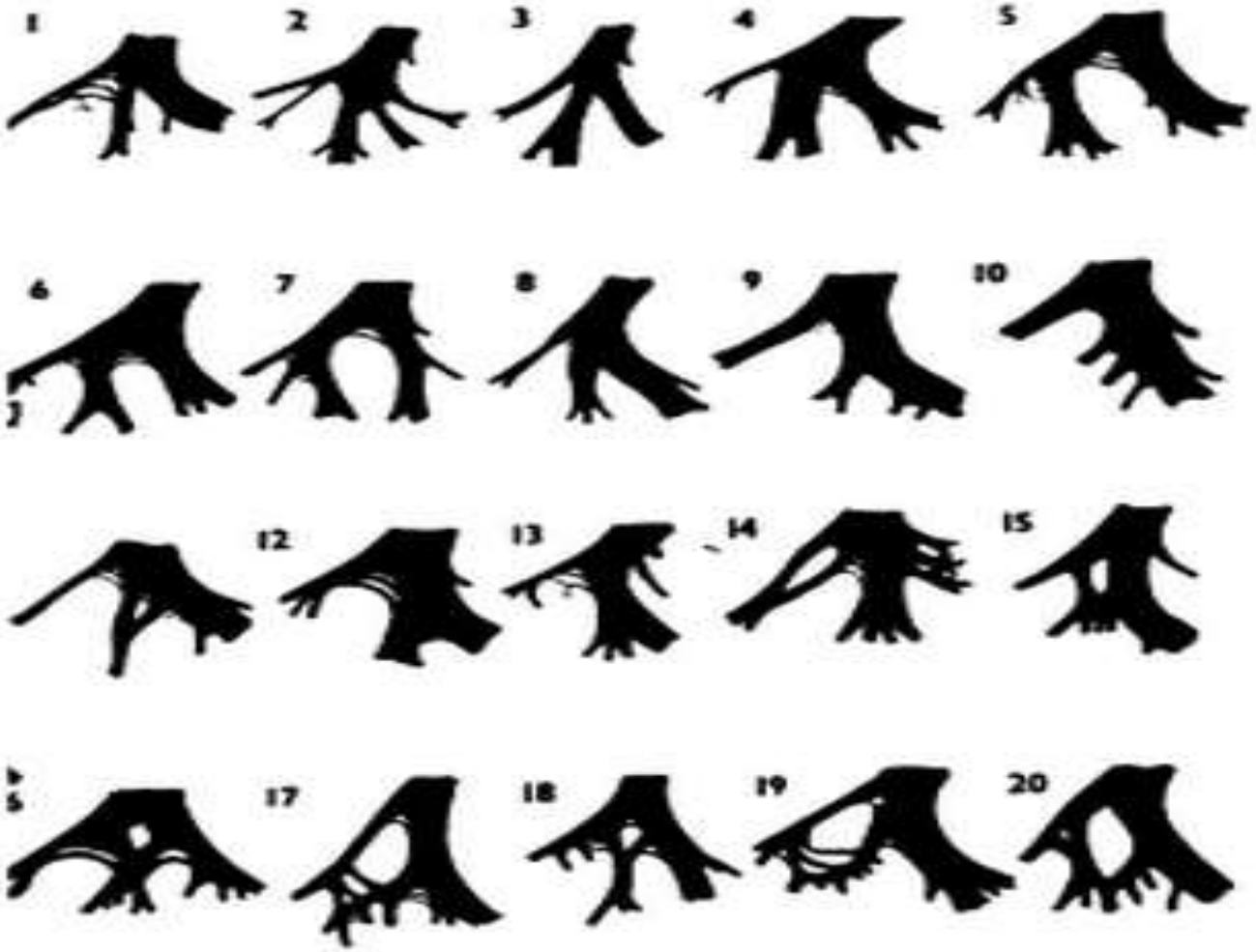
V5
V4
V1
V3
V2
+90°

Figure 2B.
Visualization of the human endocardial surface showing the Left Bundle Branch and its fascicles (Uhley HN Circulation. 1959 Sep;20:419-21)



Anatomic variations, distribution and blood supply

Anatomohistopathological studies showed that this fascicle has considerable variability in its anatomy with diverse morphologies. Thereby, five basic anatomical types are described (**Kullbertus 1973-1975-1976; Lev 1975; Demoulin 1972-1973**) (Figure 2C):



Diagrammatic sketches of the left-sided conduction system as observed in 20 normal human hearts. In this figure clearly we can see 3 fascicles following the LBB.

We divided them in a simple way in six types (**Hecht 1973**)

Figure 3. Type I anatomic variation. The left septal fascicle is born independently from the truncus of the left bundle branch (LBB).

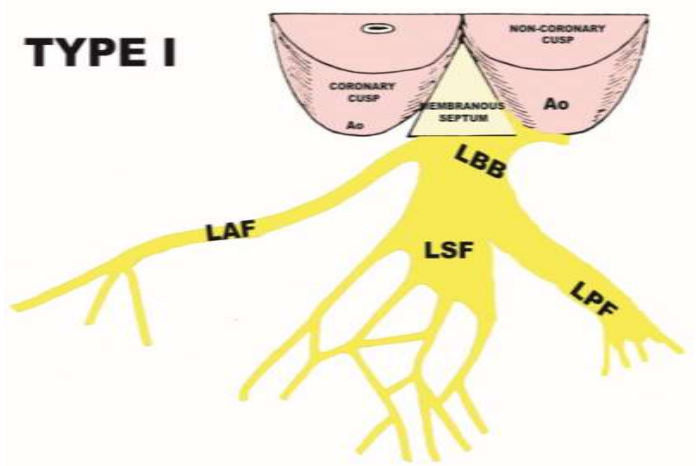


Figure 4 shows a lateral view of the endocardium of the Interventricular Septum (IVS) in the human heart (**Rosenbaum 1967**). In this example the LSF originates from the main LBB. Additionally, the LAF conducts to the Anterolateral Papillary Muscle (ALPM) of the mitral valve and the LPF straight to the Posteromedial Papillary Muscle (PMPM) of the mitral valve.

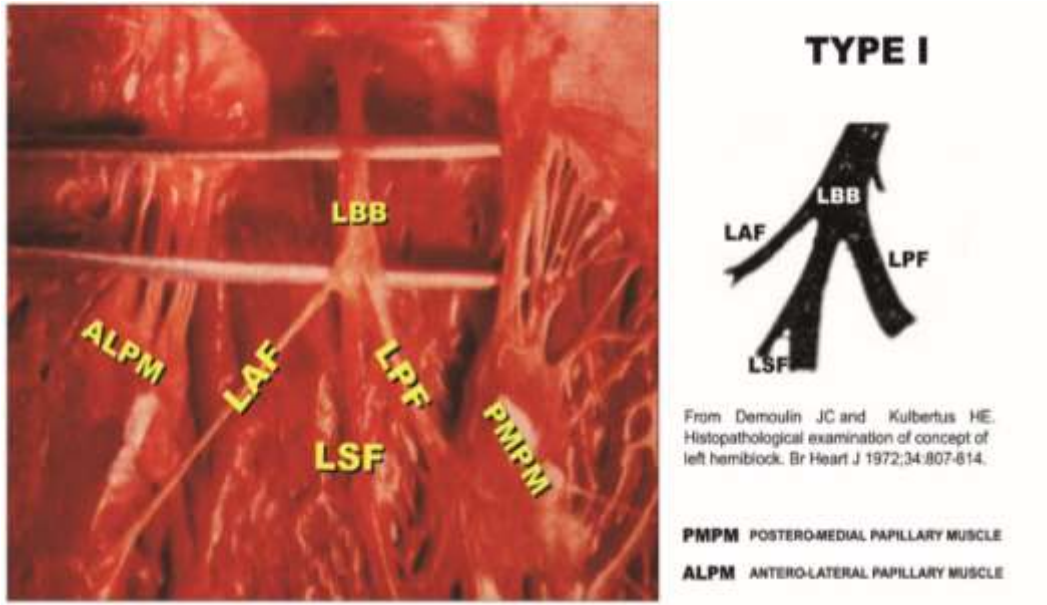
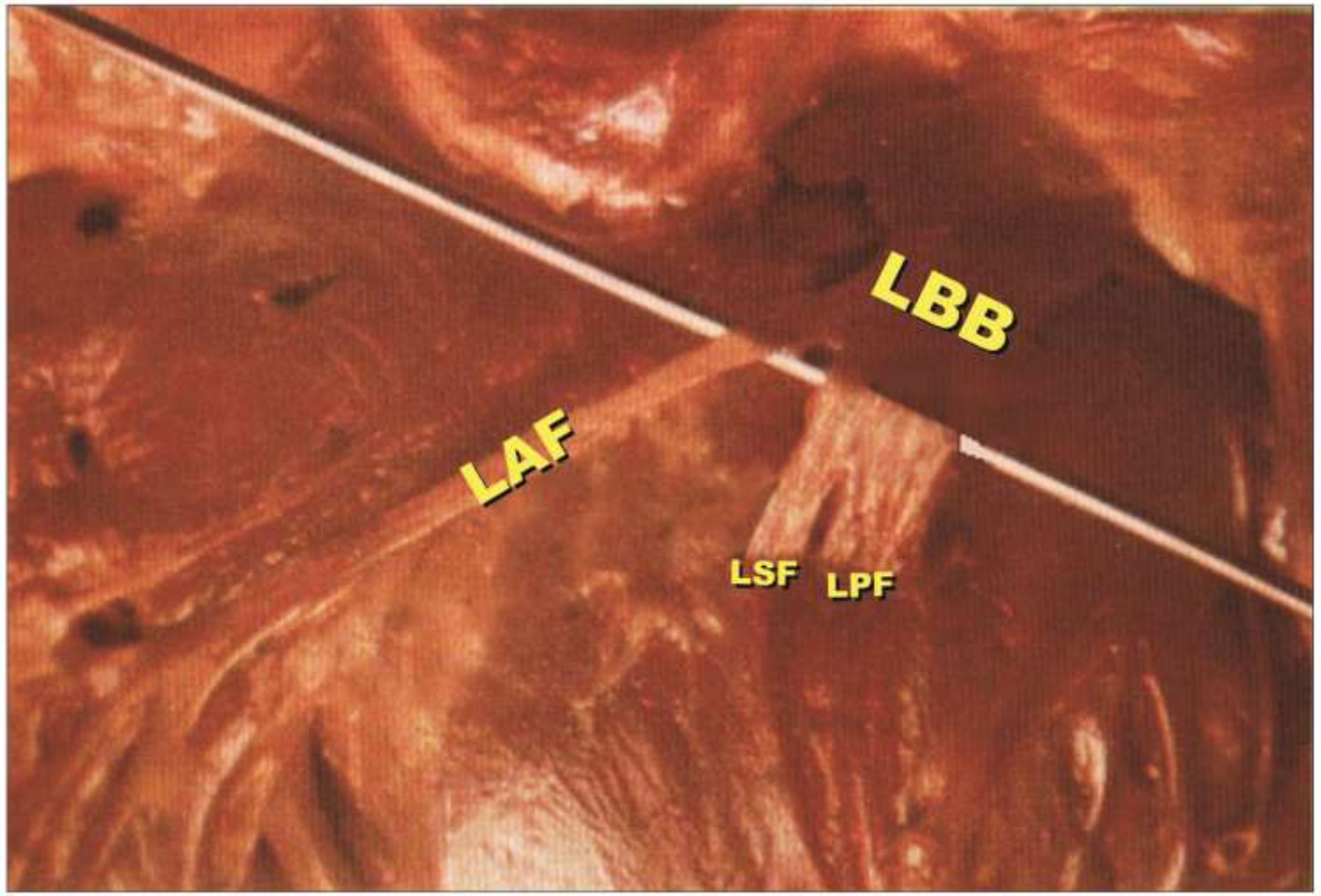


Figure 7. Demonstration of the type III LSF anatomic variation. In this figure, extracted from the original book by Rosenbaum **(Rosenbaum 1967),** the LSF originates from the LPF. Rosenbaum considered these as "false sinews or tendons" originating from the LPF.



The ventricular activation sequence

The figures 19, 20 and 21 illustrate normal ventricular activation models.

Figure 19. Sequence of normal ventricular activation

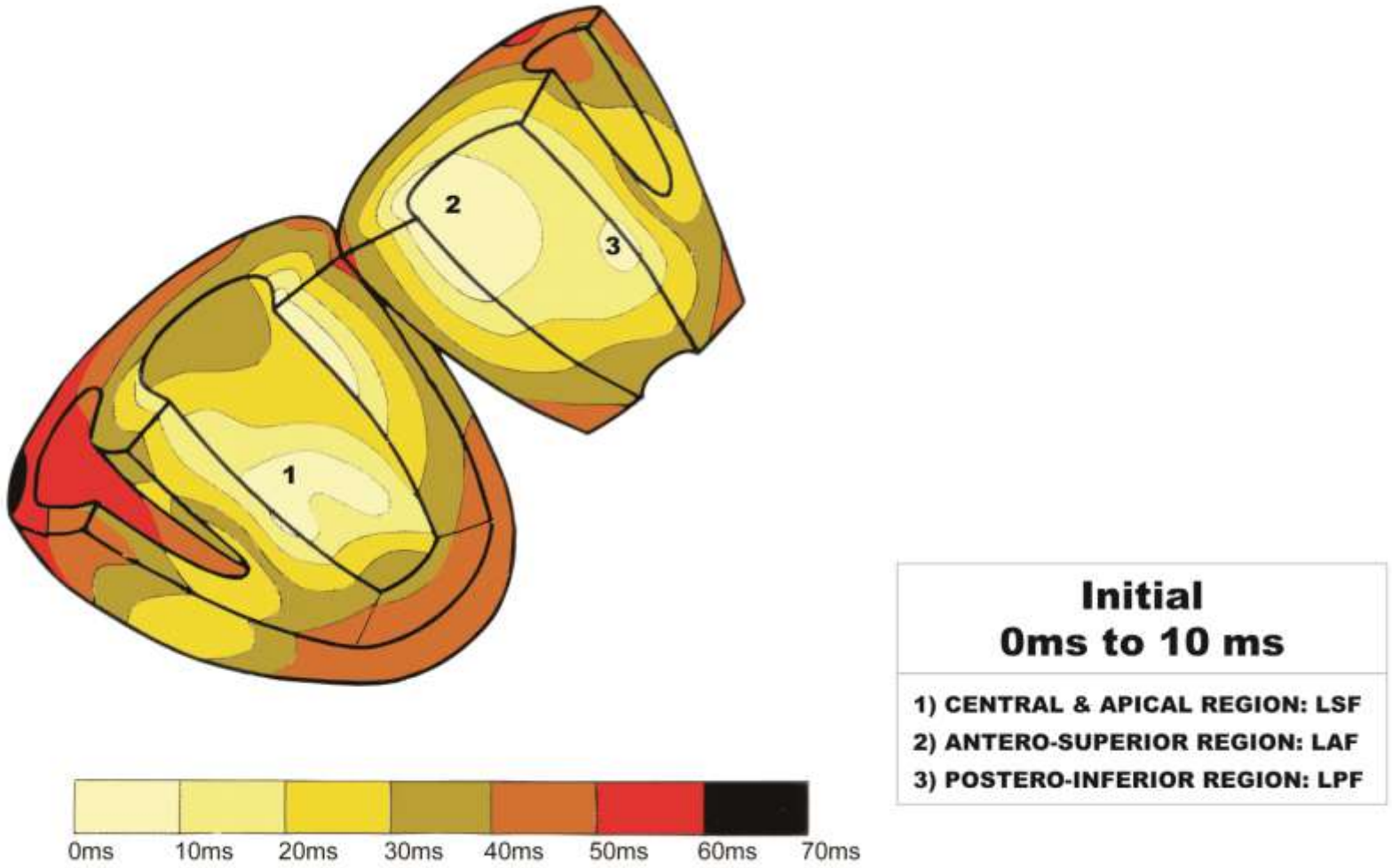
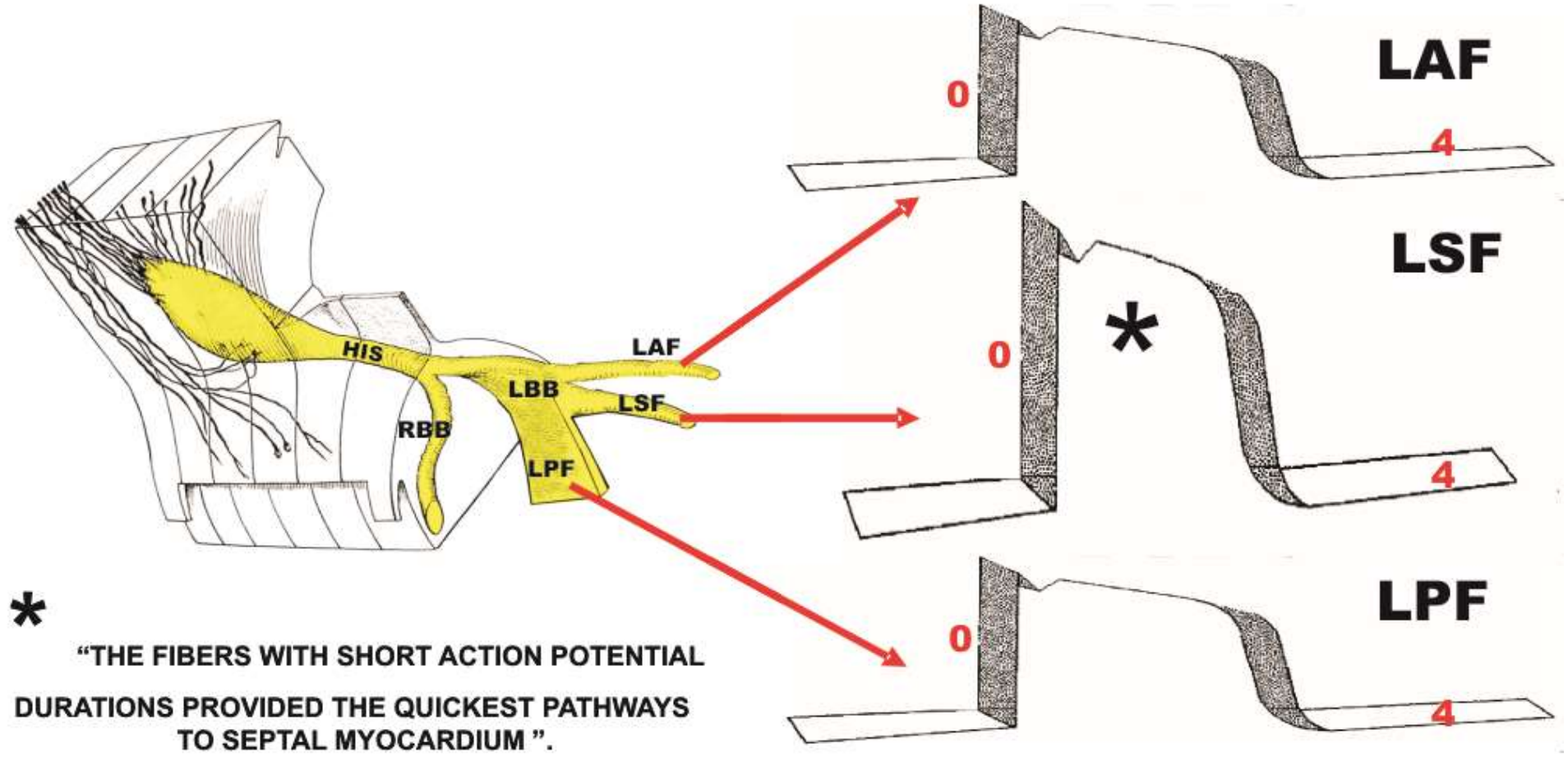


Figure 23. Differential conduction velocity on left fascicles of LBB and their action potential differences (APs)



	LAF AP	LSF AP	LPF AP
Phase 0	Lower amplitude	Greater amplitude	Lower amplitude
AP duration	Greater	Lesser	Greater
Conduction velocity	Slower	Higher	Slower

The normal amplitudes of R waves in lead V_2 are:

Table 3

Normal amplitudes of R wave in lead V_2 (mm)

Age	Mean in women	Mean in men	Range in women	Range in men
20-30	7.4	4.6	1.7-13.9	1.1-9.2
30-40	5.4	3.7	0.6-12.1	0.4-10.1
40-60	4.6	3.6	0.6-12.0	0.2-9.1

From 20 to 30 years old, R wave > 13.9 mm in women and > 9.2 mm in men is considered a criterion for PAF.

From 30 to 40 years old, R wave > 12.1 mm in women and > 10.1 mm in men is considered a criterion for PAF.

From 40 to 60 years old, R wave > 12.0 mm in women and > 9.1 mm in men is considered a criterion for PAF.

The normal amplitudes of R waves in lead V3 are inside Table 4:

Table 4

Normal amplitudes of R wave in lead V_3 (mm)

Age	Mean in women	Mean in men	Range in women	Range in men
20-30	11.6	8.2	2.2- 26.6	2.3 -17.5
30-40	9.4	7.1	2.2-22.5	0.8-23.3
40-60	8.4	7.1	1.4-11.6	1.0-17.7

From 20 to 30 years old, R wave > 11.6 mm in women and > 8.2 mm in men is considered a criterion for PAF.
From 30 to 40 years old, R wave > 9.4 mm in women and > 7.1 mm in men is considered a criterion for PAF.
From 40 to 60 years old, R wave > 8.4 mm in women and > 7.1 mm in men is considered a criterion for PAF.

The normal amplitudes of R waves in lead V4 are inside Table 5:

Table 5

Normal amplitudes of R wave in lead V_4 (mm)

Age	Mean in women	Mean in men	Range in women	Range in men
20-30	16.6	11.5	6.1- 27.7	5.0 -19.6
30-40	14.8	11.8	5.2-29.2	4.1-25.9
40-60	14.2	12.4	5.2-25.6	3.7-23.6

From 20 to 30 years old, R wave > 27.7 mm in women and > 19.6 mm in men is considered a criterion for PAF.
From 30 to 40 years old, R wave > 29.2 mm in women and > 25.9 mm in men is considered a criterion for PAF.
From 40 to 60 years old, R wave > 25.6 mm in women and > 23.6 mm in men is considered a criterion for PAF.

ECG/VCG examples of LSFB

Transient Left Septal Fascicular Block: A hallmark expression of critical proximal obstruction of Left Anterior Descending Artery

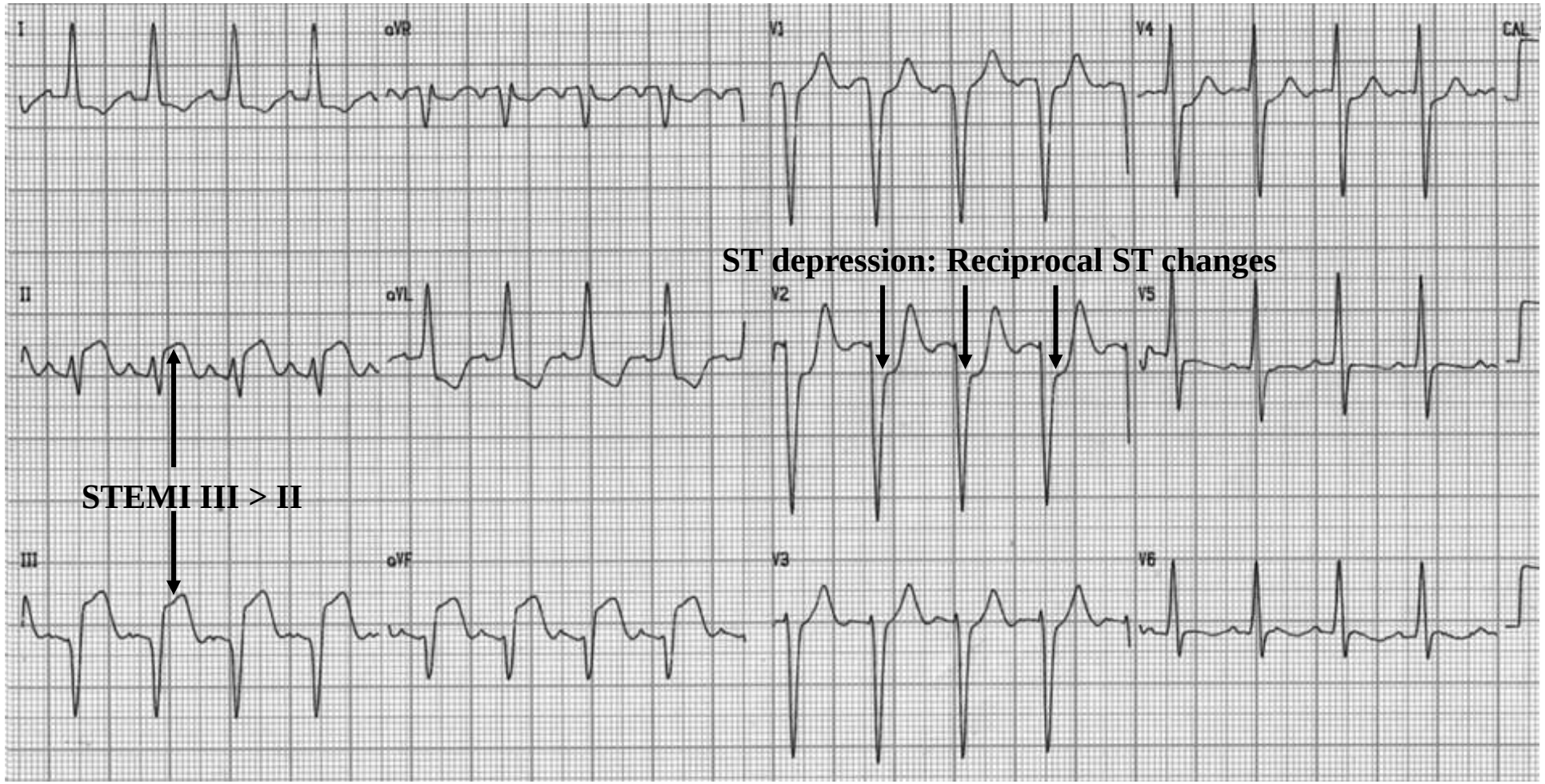
Case Report

Female, 78 yrs old, Caucasian patient, who was admitted to the emergency room with typical clinical-electrocardiographic image of ST-segment elevation acute coronary syndrome (STE-ACS). A standard 12-lead ECG was performed at admission within the first 12 hours of chest pain having started. **ECG1**. Immediately, the patient was submitted to primary Percutaneous Transluminal Coronary Angioplasty (PTCA) with successful stent placement in proximal Right Coronary Artery (RCA). Additionally, the angiocoronariography shows critical proximal obstruction of the Left Anterior Descending (LAD) before the first septal perforator (S_1). The strategy was to carry out an elective angioplasty in a second time.

A few days later, the patient returned with a typical episode of effort-induced precordial pain. **ECG2**.

An ECG was conducted on the third day after the successful PTCA of the LAD. **ECG3**.

ECG1. Standard 12-lead ECG performed at admission within the first 12 hours of chest precordial pain onset.

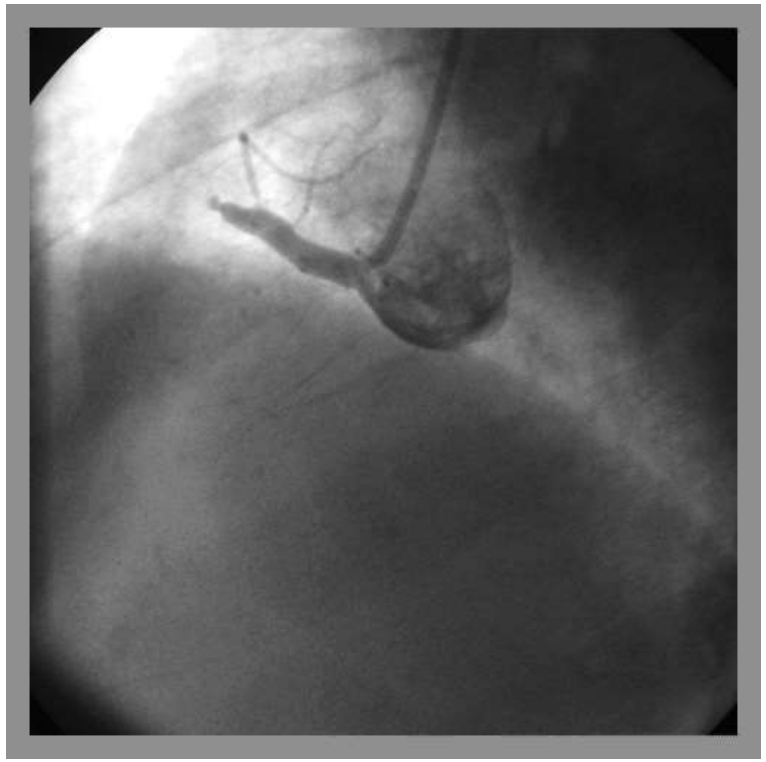


ECG diagnosis: sinus tachycardia (heart rate 125 bpm), left axis deviation (QRS axis -30º: minimal degree of Left Anterior Fascicular Block?), pathological QS waves in III and aVF followed by upwardly convex ST segment elevation ≥1 mm (inferior subepicardial injury). ST segment elevation in lead III greater than in lead II is suggestive of RCA occlusion. Additionally, ST segment depression is observed in V2. These represent reciprocal ST changes (mirror image) in leads remote from the site of acute anteroseptal wall infarction from V_1 to V_4 (marked ST- segment depression in V_2).

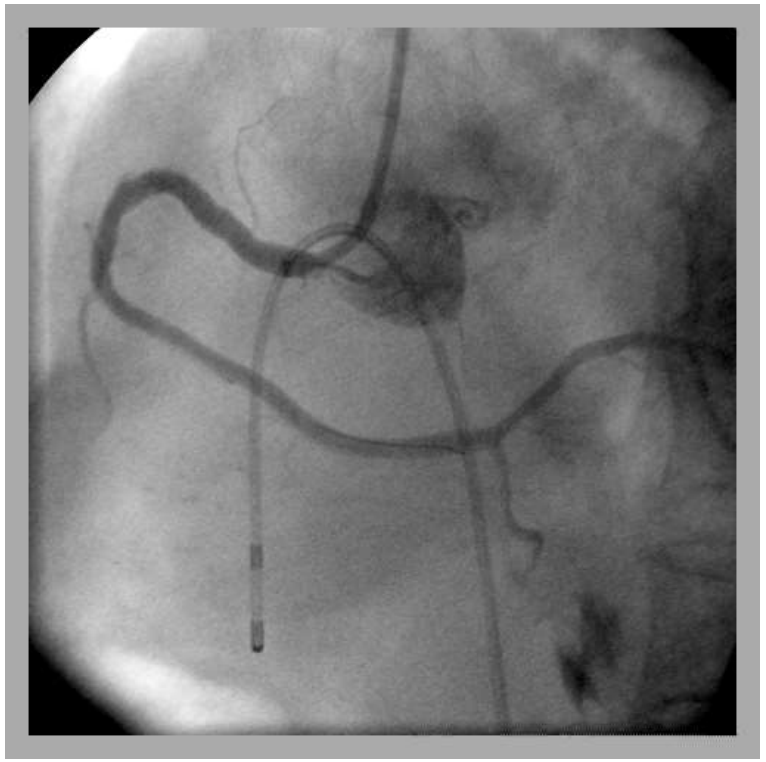
Conclusion: sinus tachycardia and inferior acute myocardial infarction consequence of RCA occlusion.

Before and after Primary Percutaneous Transluminal Coronary Angioplasty (PTCA)

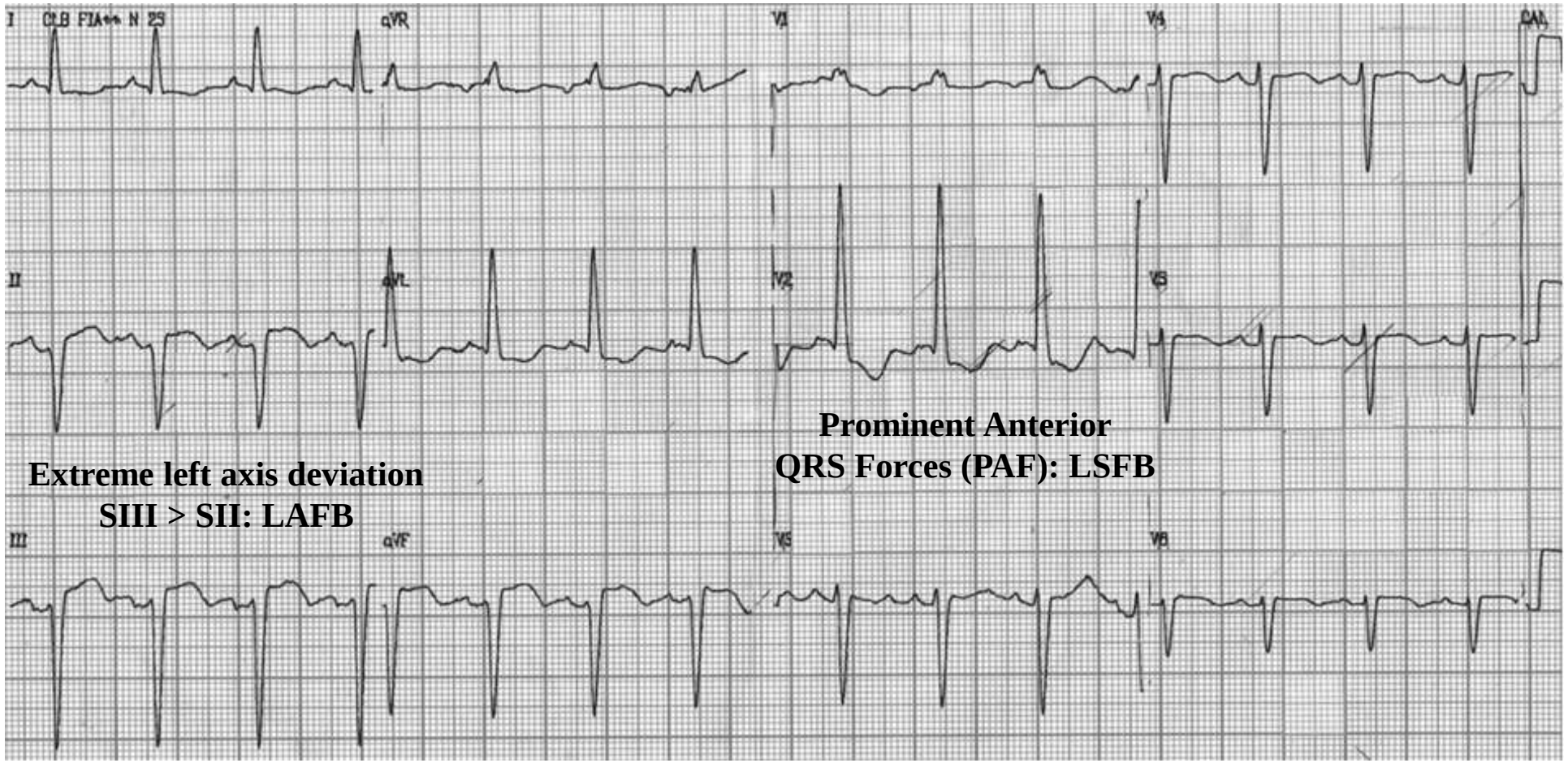
Before



After

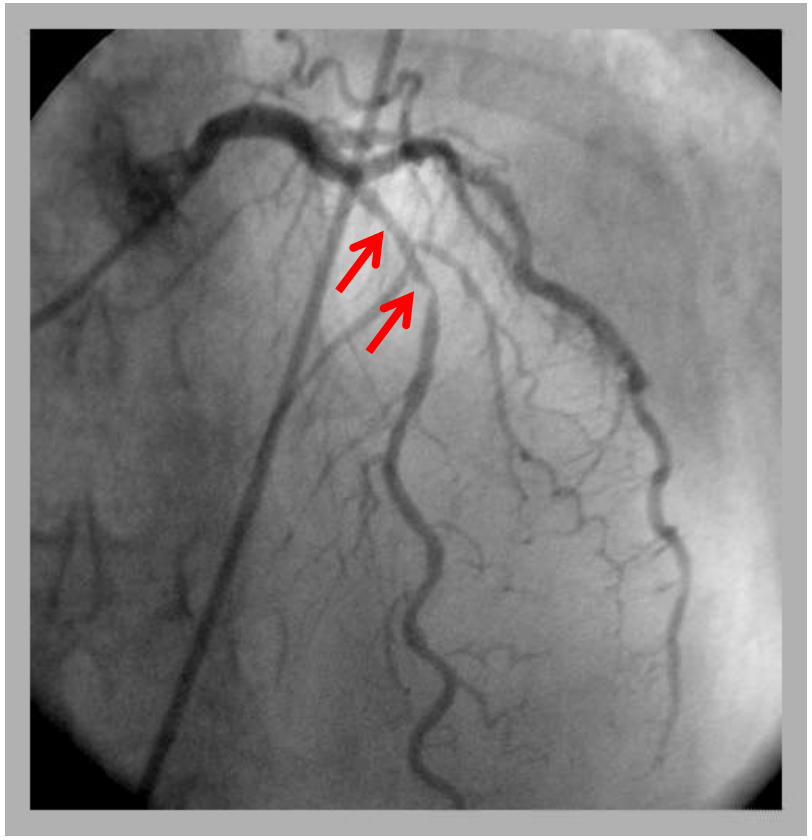


ECG2. Performed immediately after effort-induced episode of typical angor pectoris

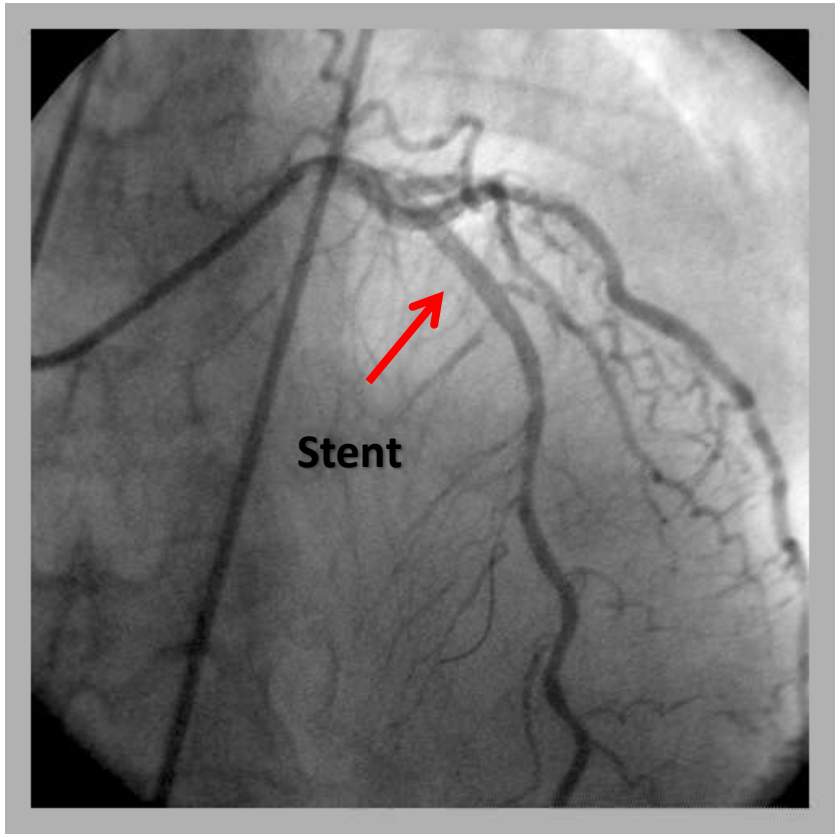


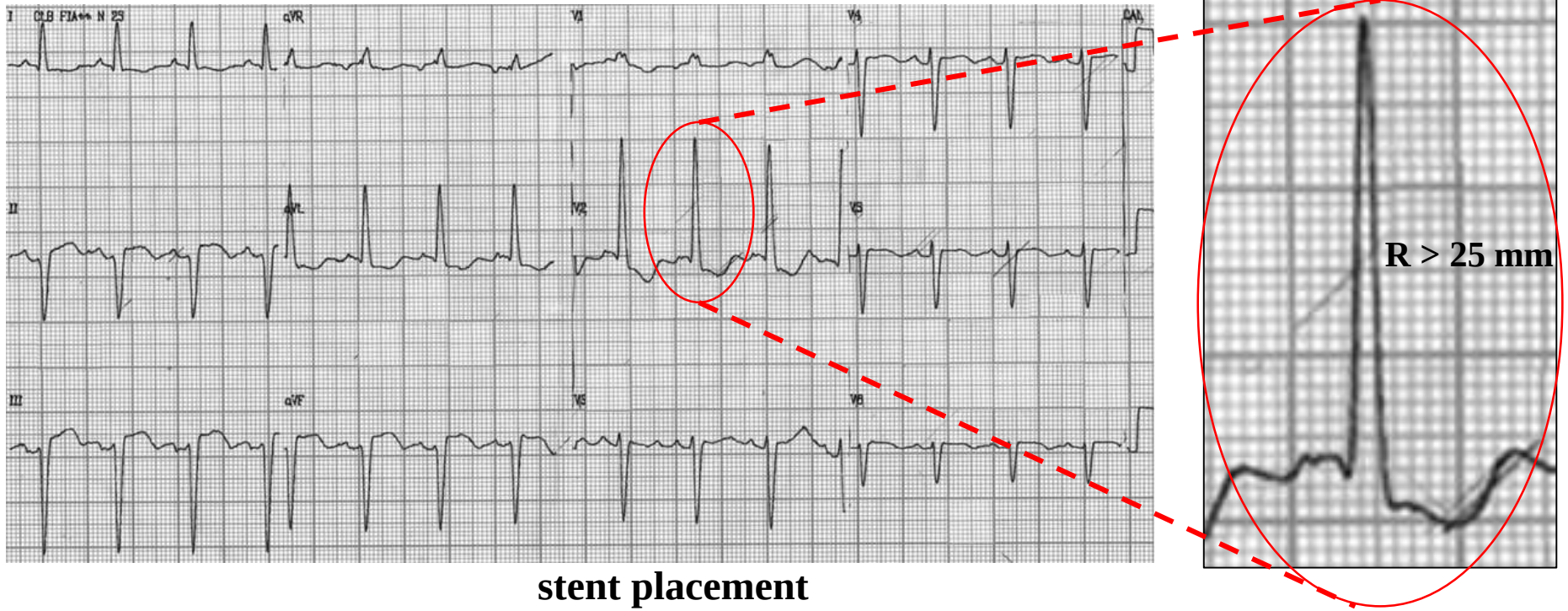
ECG2 diagnosis: sinus rhythm, heart rate 94 bpm, extreme QRS left axis deviation in the frontal plane (QRS axis -70º), QRS duration 115 ms, qR pattern on I and aVL, rS pattern on inferior leads, SIII>SII, SIII>15 mm and rS pattern in left precordial leads V5-V6: Rosenbaum's type IV Left Anterior Fascicular Block (LAFB). Additionally, inverted T wave on left leads I, aVL, V_5 and V_6 are observed; ischemic T waves?
QRS duration <120 ms (close to 115 ms). qR pattern in V_2 lead, embryonic initial q wave in V_2 followed by very tall R wave in V_2 (R wave >15 mm): Prominent Anterior QRS Forces (PAF), absence of initial q wave on left precordial leads: Left Septal Fascicular Block (LSFB).
Conclusion: bifascicular left fascicular block: LAFB associated with LSFB.

Before



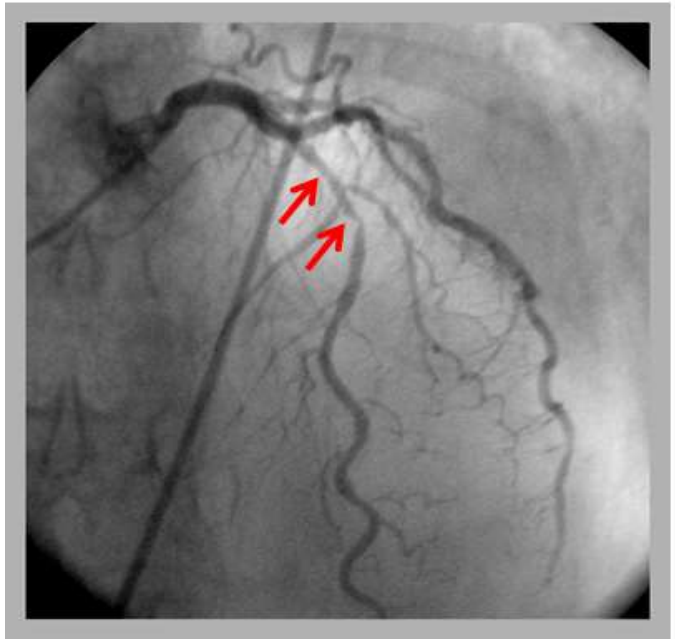
After





stent placement

Before



After