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Forensic usefulness of the silicone rubber cast of the cardiac vessels

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Summary. Adequate examination of the coronary arteries at forensic autopsy is often difficult. No matter whether the arteries are opened longitudinally or transversely, each method has its disadvantages. A technique making silicone rubber casts of the cardiac vessels providing simultaneous angiography is described. The method allows the three-dimensional precise assessment of stenotic lesions of the coronary arteries. It is concluded that the method examined could be useful for the forensic problems.

Key words: Silicone rubber cast, coronary atherosclerosis – Coronary atherosclerosis, simultaneous angiography

Zusammenfassung: Es ist oft schwierig, bei den forensischen Sektionen die angemessene Untersuchungsmethode der Coronararterien zu wählen. Ob die Coronararterien längs oder quer und serienmäßig geschnitten werden: es gibt bei allen Methoden Nachteile.

Eine Technik zur Ausführung von Silicone-Gummi-Korrosionspräparaten der Blutgefäße des Herzens, die gleichzeitig Angiographie bedeutet, wird beschrieben. Das Silicone-Gummi-Korrosionspräparat erlaubt die dreidimensionale und genaue Beurteilung der Coronararterienstenose. Daraus wird gefolgert, daß die beschriebene Methode für forensische Fragestellungen von Nutzen sein könnte.

Schlüsselwörter: Silicone-Gummi – Korrosionspräparat, Coronararteriensklerose – Coronararteriensklerose, Nachweis des Umfangs im Korrosionspräparat

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Introduction

There is a great need for a satisfactory method of quantitating the severity of coronary atherosclerosis, and many investigations of coronary artery disease by different approaches have been reported [1]. Usually, the coronary arteries are examined either by cutting across them transversely or by opening longitudinally with fine scissors, which provides a measure of the extent of arteriosclerotic disease. Both techniques, however, are generally accepted as inadequate despite efforts to render quantitative observations of the coronary arteries. As another technique for coronary artery disease, postmortem coronary angiography has been reported [1–5]. The angiography, however, suffers from the disadvantage that the method is essentially two-dimensional, and further examination is required to verify the validity of changes seen on the radiographs. There have been several studies on the casts of the cardiac vessels for the purpose of the anatomic usage [6, 7]. Robbins and Fish [8] reported an angiographic technique providing a simultaneous cast of the coronary lumen. The conventional corrosion casts that have been obtained, however, are rigid and fragile, and they have not been well appreciated for pathologic usage.

This report presents a new examination method with the cast of the cardiac vessels using silicone rubber and some interesting findings on coronary atherosclerosis obtained by the method.

Materials and methods

Thirty human hearts, representing all stages of coronary atherosclerosis and concomitant heart disease, were used in the preparation of the casts. They originated from 21 men, nine women, and the age range was 15–77 years with a mean of 47 years. Postmortem clots were removed by irrigation with saline, and the heart muscle was squeezed slightly to reduce the amount of blood and saline in the cardiac vessels. The aorta was cut transversely about 30 mm above the coronary ostia. The aortic valves were sutured in the closed position. Polyethylene cannulas of suitable size were placed into the coronary ostia and tied with purse string sutures.

As injection medium, silicone rubber (Silicone KE-24: Shin-Etsu Chemical Co., Ltd., Tokyo, Japan) was used. It was colored red for coronary artery system and blue for the coronary venous system by silicone coloring agents (Silicone K-Color R-21 or B-21). The colored silicone rubbers were freshly prepared for use. Fifteen drops (0.6 g) of curing agent (CAT-RM) and 10 ml of catalyst (CAT-24) were added for 100 g of silicone rubber.

Using hand injection, the red injection material was instilled into the left and right coronary arteries with a 50 ml disposable syringe. The force of hand injection was carefully increased so that branches and collaterals were filled eventually. The final injection pressure was between 150 and 180 mm Hg. The progress of the injection could be seen as silicone rubber flowed into superficial arteries. After filling coronary arteries with red silicone rubber, the cannulas were taken out. Then, the red silicone rubber was injected into the cut end of the aorta, and the aortic sinus was filled with it. The heart was left in water for 1 h till the silicone rubber set.

After setting, soft X-ray angiograms of the heart were taken in four different projections. Then, the blue silicone rubber was injected into the coronary sinus and the right atrium with the same injection technique. After about 24 h in cold water, the injected mass was completely solidified. It was sometimes necessary to place wet cottonwool inside the soft-walled ventricle to assist their expansion. The heart was then placed in 15% potassium hydroxide solution at 50°C for 24 h for digestion of the muscle tissue from the silicone rubber cast of the vessels. On removal from the potassium hydroxide solution, the cast was gently floated in water and care-

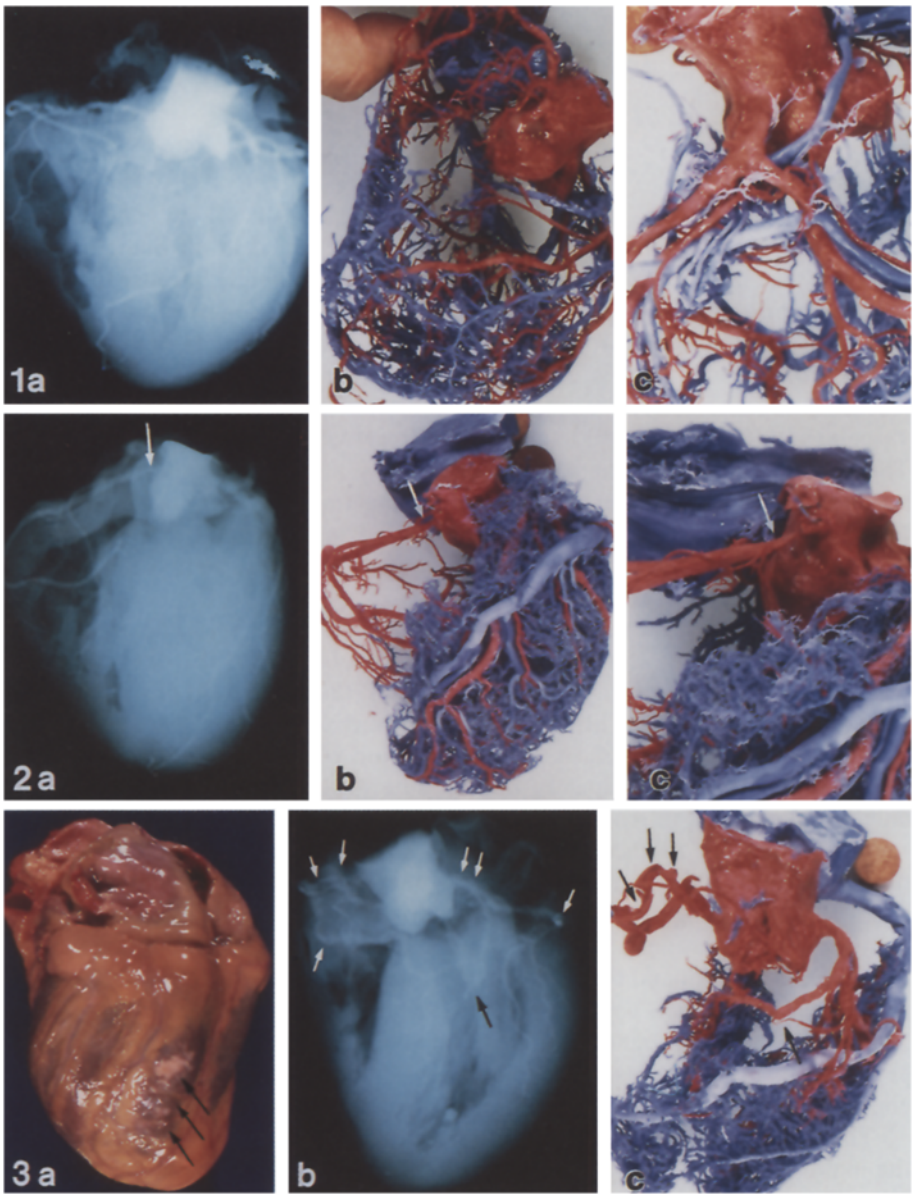

Fig. 1a–c. Coronary angiogram (**a**), silicone cast of the cardiac vessels (**b**), silicone cast of the left coronary artery from its root to its bifurcation (**c**). The 53-year-old man died of liver cirrhosis

Fig. 2. Narrowing of the main segment of the right coronary artery. There is a good correlation between the angiogram and the silicone cast *(arrows)*. The 43-year-old man died of gastric ulcer

Fig. 3a–c. The heart viewed from behind. Old infarction scar *(arrows)* (**a**), coronary angiogram. Calcification of the left coronary arterial wall, complete obstruction of the first branch of the left anterior interventricular branch, and filling deficits of the right coronary artery *(arrows)* (**b**), silicone cast. Complete deficit of the first branch of the left anterior interventricular branch and characteristic narrowings of the main segments of the left and the right coronary arteries *(arrows)* (**c**). The 61-year-old man died of myocardial infarction

fully washed with tap water to remove debris still lodged within the cast. The preparation was then air-dried.

Results

Excellent models of the vascular lumina were obtained in all human hearts. Usually, the anterior cardiac veins were not filled completely because they open independently into the right atrium. The casts of the coronaries accurately reproduced the bilateral coronary ostia and the main segments of the left and right coronary arteries (Fig. 1). When the angiograms of a heart with heavily calcified and atherosclerotic arteries demonstrated narrowing, the concomitant vascular model was distorted and showed irregularity and narrowings (Fig. 2). The reproductions of the narrowings, roughings, and luminal deformities in the sclerotic as well as the recently occluded coronary arteries were faithful. In general, there was good correlation between the angiograms and the silicone casts. This was true of the relatively normal coronary systems as well as the severely sclerotic ones.

In some cases, however, there were discrepancies between the angiograms and the silicone casts. In the heart of a 61-year-old man, which showed an old infarction scar of the left myocardium (Fig. 3a), the angiogram of the left coronary artery demonstrated little luminal deformity of the main segment, though there were flecks of calcification in the region of its wall and the complete obstruction of the first branch of the left anterior interventricular branch. The angiogram of the right coronary artery showed slight enlargement of the main segment with some filling deficits (Fig. 3b). From the angiogram, it seemed that there was little stenosis in the main segment of the left coronary artery and slight stenotic changes in the right coronary artery. The cast of the main segment of the left coronary artery was thin and twisted and showed that its lumen had a central slitlike and twisted form. The first branch of the left anterior interventricular branch was completely deficient as it was shown by the angiogram. The cast of the main segment of the right coronary artery was also thin from its proximal to distal main segment and showed that its lumen had an eccentric crescent slitlike form (Fig. 3c).

The central slitlike and twisted lumen was characteristic of the narrowing of the main segment of the left coronary artery (Fig. 4). Not a few casts of the left coronary arteries of old people, especially of those who had hypertension as well as coronary disease, showed such form. On the other hand, the eccentric crescent slitlike narrowing was characteristic of the main segment of the right coronary artery (Fig. 5a). Furthermore, as another characteristic narrowing of the main segment of the right coronary artery, an eccentric crescent slitlike form with central protuberance was also observed (Fig. 5b).

Discussion

In assessment of coronary artery disease, we made three-dimensional replicas introducing silicone rubber as injection material into the cardiac vessels. In

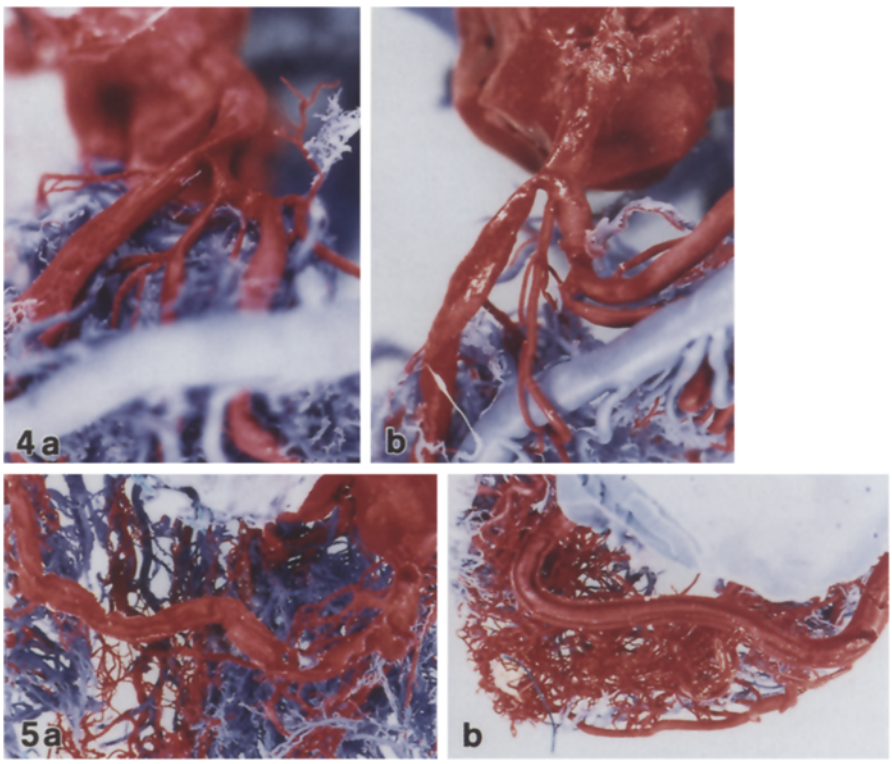

Fig. 4a, b. Characteristic slitlike narrowing with twisted appearance of the left coronary artery. The 43-year-old man had hypertension (**a**), the 77-year-old man had hypertension and myocardial infarction (**b**)

Fig. 5a, b. Characteristic eccentric crescent slitlike narrowing of the right coronary artery. The 61-year-old man died of myocardial infarction (**a**), eccentric crescent narrowing with central protuberance of the right coronary artery. The 62-year-old woman had coronary disease (**b**)

contrast to the postmortem coronary angiogram, which is essentially two-dimensional, the technique of making silicone casts offers many advantages. If a radiopaque and colored contrast material is desired, the silicone rubber is most satisfactory. The durable non-shrinking silicone models of the arterial lumina constitute a permanent three-dimensional record, and the coronary artery keeps its original position by a support of the cast of coronary venous system. Since the silicone rubber cast is flexible, it is possible to observe the narrowings of the coronary arteries more precisely by touching the cast with our fingers without damages. The silicone cast of the heart vessels could be made from the hearts which were decomposed and worth little examining histologically. Furthermore, inasmuch as the representative portions of myocardium can be simultaneously available for the histological study, it is possible to obtain the accurate data on myocardial ischemic lesions. If histological examination of the coronary arteries is required, the arteries may also be taken after being slit longitudinally with a scalpel, and they are lifted free from the cast of the arteries.

From the silicone rubber casts of the heart vessels, we observed the degree and the mode of irregularity, obstruction, and narrowings of the coronary arteries three-dimensionally as compared with their angiograms. A good correlation between the casts of the coronary arteries and their angiograms was obtained in general. However, there were occasionally slitlike narrowing or eccentric crescent narrowings of the main segments of the left and the right coronary arteries of which angiograms did not show the distinct narrowing. The discrepancies were caused by the fact that the slit in its widest diameter was viewed on the angiogram and this wide image was interpreted as that of a normal artery. Though this error might be corrected when several projections are made, there remains a problem [9].

It is said that depending on the distribution of atherosclerosis, a narrowed lumen may lie either in central location (when the atheromatous process is circumferential) or, more commonly, in an eccentric position and the eccentrically located lumen may either be slitlike or may vary in shape. The three types of lumen (central, eccentric slitlike, and eccentric polymorphous) have been observed approximately in equal distribution among atheromatous segments of coronary arteries [10]. The present work, however, revealed that there are central slitlike lumina with twisted form and eccentric crescent slitlike form with or without central protuberance, as modified forms of central circumferential narrowing and eccentric slitlike or eccentric polymorphous form, respectively. The central slitlike narrowings with twisted form was characteristic of the left main coronary artery. The twisted slitlike form seemed to be caused by the twisted blood flow due to the direction of the left coronary artery, i.e., the left coronary artery curves at its root and soon divides into two major branches, anterior interventricular and circumflex branch. On the other hand, the eccentric crescent slitlike narrowing with or without central protuberance was characteristic of the right coronary artery. It seemed to be caused by the straight blood flow in the main segment of the right coronary artery. The eccentric crescent narrowing with central protuberance was considered to be the preceding stage of the eccentric crescent slitlike narrowing.

The silicone casts of the heart vessels are particularly useful as a new examining method of the removed hearts in forensic autopsy and will permit virtually a detailed reconstruction of the distribution and location of the vascular disease.

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