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Frequency of acute asymptomatic myocardial infarction and an estimate of infarct age in cases of abrupt sudden death observed in a forensic autopsy material

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Abstract

The aim of this study is to determine the frequency of acute infarcts at autopsy in cases of unexpected abrupt deaths in persons with coronary heart disease. In addition, we want to estimate the time between onset of infarct and death based on evolving tissue changes in the infarct known to occur during the first hours. Thirty cases of unexpected, abrupt deaths were selected from a forensic autopsy material. Half of them had a preliminary diagnosis of coronary heart disease, the other half a preliminary diagnosis not involving the heart or chest area. Complete autopsies were performed. The myocardium and the coronary arteries were sampled and examined without knowledge of the gross findings or to which group the case belonged. Myocardial infarcts and acute coronary changes were found in both groups, less frequently in the non-coronary group. The age of the myocardial and coronary lesions was estimated by observing morphological characteristics changing with time, *e.g.* increasing polymorphonuclear leucocytes in the infarcted myocardium, and increasing amount of fibrin in thrombi. The majority of cases in the coronary group died with an extensive asymptomatic myocardial infarction, which probably had lasted 5–6 hrs or less. Acute changes in the right coronary artery and its area of supply prevailed. Acute myocardial infarcts were observed also in a minority of the non-coronary group, but myocardial infarction was not the cause of death in any of them. Abrupt coronary death is most often preceded by an extensive asymptomatic myocardial infarction within the last 5–6 hrs.

Keywords: age of myocardial infarct • $CD15^+$ cells • coronary atherosclerosis • coronary thrombosis • myocardial infarction • sudden death

Introduction

In our forensic service we observed over the years many cases of abrupt, unexpected death. Typical findings might be a recent myocardial infarct or no infarct, possibly a myocardial scar and varying degree of coronary atherosclerosis with or without a recent occlusion. The incident had at times been precipitated by a stress situation.

It is known that myocardial infarction may proceed without any significant symptoms [1–4], that sudden death may be caused by an acute arrhythmia [5–7], and that arrhythmias may be precipitated by physical or mental stress [8–11].

It is not exactly known, however, which pathological processes are going on in the myocardium and the coronary arteries in the last minutes and hours prior to the abrupt unexpected coronary death. In this study we try to shed some light on these processes. How often is there an asymptomatic infarct and how long has the infarct lasted before the abrupt death? Are there also acute occluding changes in the coronary arteries?

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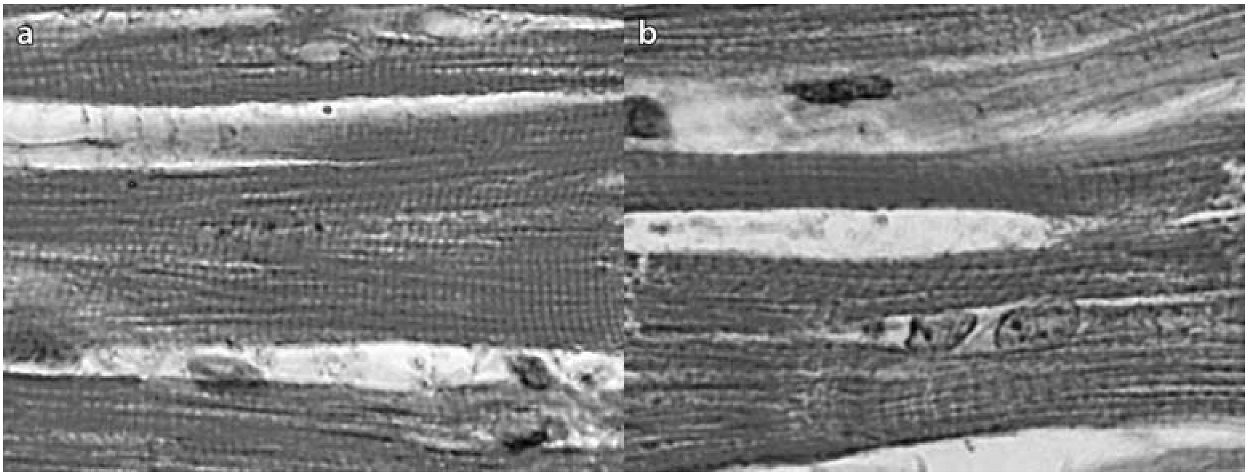

Fig. 1 Histological section of the myocardium from one of the cases of coronary heart disease with signs of a recent myocardial infarct (**a**) and an area of myocardium without myocardium infarction (**b**). The diagnosis in Fig. 1a is based on the presence of oedema, hyperaemia and irregular cross-striation of the muscular fibres. Haematoxylin-eosin (×880).

Materials and methods

Altogether 30 cases of abrupt death under police investigation were collected consecutively and examined post mortem at the Institute of Forensic Medicine, University of Oslo, Norway, over 11 months.

In half of the cases the history, information about the circumstances around the death, and external examination of the body before the autopsy, gave us reason to believe that the cause of death was an underlying coronary heart disease. The death was witnessed, abrupt, and unexpected, occurring during daily activities: walking, working, travelling, dancing, etc.

The remaining 15 cases, serving as controls, were also collected consecutively with the following criteria: the persons should be adults and die abruptly of a cause not involving the heart or chest area. Their history and the circumstances around their death should not indicate coronary heart disease.

Histological examination of the autopsy material was done without knowing neither which group the individual case belonged to, nor the gross findings. After opening the code it turned out that several of the non-coronary cases had signs of coronary heart disease after all. We did not, however, re-allocate any case after the initial selection. There remained an important difference between the groups: one group of persons died abruptly of their coronary heart disease, the other group died abruptly of something else, mainly violence.

Complete autopsy was carried out in all cases. The myocardium was examined closely with regard to signs of recent myocardial infarction. The presence of fresh infarcts by macroscopic examination was revealed by observing a slightly pale yellowish zone with blurring borders on the cut surface of sections parallel with the myocardial surface. A negative reaction (i.e. lack of staining) with nitroblue tetrazolium solution was used as a help in the gross identification of recent infarcts. Abnormal findings (recent and older infarcts, scars, fibrosis) were described and delineated on cardiac schemes. Material from anterior, posterior and lateral walls of the left ventricle, as well as from the lateral wall of right ventricle, was sampled in a standardized manner, fixed in formalin and embedded in paraffin. Histological sections were cut in parallel with the heart surface and stained with haematoxylin-eosin and Lendrum's Martins-Scarlet-Blue (MSB) fibrin stain. Additional sections were sampled from the myocardium, for example septum when the macroscopic findings made it wanted.

The microscopic diagnosis of acute myocardial infarcts was based on the presence of the characteristic histological findings established by Mallory *et al.* [12] and Sommers and Jennings [13]: diffuse granularity and disorganization of myofibrillar structure with loss of the regular cross-striation pattern in longitudinal sections of the contractile cells, as well as capillary hyperaemia and myocardial oedema. (Fig. 1). The disturbed cross striation is best observed without the condenser lens. Hypereosinophilia of the muscular cells, contraction bands, obvious wavy muscle fibres and tissue infiltration of polymorphonuclear leukocytes within or outside the myocardial microcirculatory vessels were supporting, but not decisive features.

All muscular sections were stained with the immunohistochemical reactant towards membranolytic C5b-9 membrane attack complex of the complement (C9)(anti-C9 Primary Antibody, Ventana Medical Systems, Illkirch, France), first recommended as a marker of necrotic skeleton muscular cells by Engel and Biesecker [14], later by others as a marker also of necrotic myocardial muscle cells [15–17].

The myocardial tissue was also stained with the immunohistochemical reactant towards antibody CD15 (1G10 or Leu-M1) (anti-CD15 Primary Antibody, Ventana Medical Systems, Illkirch, France). This antibody stains the neutrophilic polymorphonuclear leucocytes, but also monocytes and their derivatives [18–20]. Based on the experience that polymorphonuclear leucocytes are increasingly attracted to infarcted myocardial area during the first hours after its onset [21], we expected to obtain a rough estimate of the relative age of the infarct by counting the number of labelled cells in sections of infarcted myocardium.

The number of CD15 positive cells was counted by two of the authors (ESM and LJ) in three visual fields of the myocardium in a microscope with objective 10. Cells within the microcirculatory vessels were included, whereas cells within venous 'lakes' were excluded. The mean of the three counts was used as representative for the tissue under examination. Whenever an infarct was present, the counts were determined in the infarcted area. In cases with no infarct, the areas for counting were selected at random.

In all cases the coronary arteries was dissected free from the heart and decalcified shortly. The three main arterial stems were cut in 3–4 mm thick

Table 1 Number of persons with acute and healed myocardial infarcts

Type of lesion	Coronary group	Non-coronary group
Acute infarcts:		
Macroscopic examination	8	2
Microscopic examination	13	7
Myocardial scars:		
Macroscopic examination	12	6

Difference between the lesions in the two groups:
Macroscopic acute infarcts: $P = 0.05$
Microscopic acute infarcts: $P = 0.05$
Scars: $P = 0.06$

transverse sections; 8–12 sections from circumflex branch, 15–25 from left coronary artery and its descending branch, and 20–35 from right coronary artery.

The maximum degree of stenosis in each coronary artery was estimated as per cent of the original lumen. The acute changes in the arteries were classified according to Jørgensen *et al.* [22]. The approximate age of the thrombi was based on experience from experimental thrombi under controlled conditions [23–26]. Old, organized and/or re-canalized thrombi were diagnosed on the basis of partial occlusion of the lumen with granulation or scar tissue with multiple de novo formed channels [27–29].

Differences between the two groups of deceased are presented and analysed statistically using t-test for comparison of the measurements and Fisher's exact probability test on the numeric counts of the quantifiable characteristics. The P-values presented are two-tailed and the level of significance was set at $P \leq 0.05$.

Results

In all 15 cases allocated to the group of coronary heart disease the diagnosis could be confirmed by the autopsy findings.

In the group of 15 non-coronary cases, the majority had a violent cause of death: 10 shot themselves in the head, two had severe head injuries and one was killed by severe knife wounds in the neck. The remaining two died suddenly by massive aspiration of food material into the tracheal-bronchial tree.

Seven of them had recent myocardial infarcts; one additional case had recent ruptured necrotic plaque with intraplaque haemorrhage in the right coronary artery with no identifiable myocardial infarction.

Both groups comprised mostly middle-aged and elderly persons, the majority of them being men, four women in the coronary group, only one woman in the non-coronary group. They differed with a more narrow age span in the coronary group (41–79 years) compared to the non-coronary group (39–84 years). The heart weight and body mass index (kg/m^2) were somewhat greater in the coronary heart group than in the non-coronary group but the differences were not significant.

The frequency of one or more recently infarcted myocardial areas is shown in Table 1. Recent myocardial infarction was diagnosed by both macroscopic and microscopic observations, applying the criteria described in Material and methods. The number of cases with recent infarcts was greater in the coronary group compared to the non-coronary group at borderline significance ($P = 0.05$). Also the occurrence of macroscopic scars following previous incidents of myocardial infarction was greatest in the coronary group, but this difference did not quite reach the level of significance.

The localization of macroscopic infarcts differed in the two groups (Table 2): infarcts of the posterior left ventricular wall occurred significantly more often in the coronary group compared to the non-coronary group ($P = 0.0007$).

By microscopy, however, infarcts were found to be spread throughout the left ventricle: in the majority of cases in the coronary group microscopic infarcts occurred in all three areas of arterial supply. In the non-coronary group the infarcts involved one, or at the most, two areas of arterial supply. In all areas of arterial supply the frequency of recent infarcts was significantly greater in the coronary group than in the non-coronary group (Table 2).

The extension of the infarcts were not quantified, neither in the transverse direction through the thickness of the wall, nor in the longitudinal direction parallel with the surface. Nevertheless, the impression was that most of the infarcts in the coronary group were more extensive than those in the non-coronary group.

Scar tissue from previous infarcts were significantly more frequent in the posterior wall of the left ventricle in the coronary group than the non-coronary group ($P = 0.027$) (Table 2).

Myocardial sections stained with C9 showed positive reaction, spotty or more confluent (Fig. 2A), in less than half of the infarcts in the coronary group. It was positive in only one of the infarcts in the non-coronary group.

With the immunohistochemical reagent CD15 we were able to quantify the number of positive cells in infarcted and non-infarcted areas in a standardized manner (Fig. 2B and C). Table 3 shows that cases without infarcts, and in some of the cases with infarcted areas as well, had low numbers of positive CD15 cells (< 20 per visual field). The majority of cases with infarcted areas had > 20, or even > 30, some up to > 100 positive CD15 cells per visual field (Fig. 2C) (Table 6). The differences in number of positive cells between the coronary and non-coronary groups (disregarding whether infarct was present or not) was moderately significant in the three arterial areas of supply of left ventricle ($P = 0.0457$, 0.0227 and 0.0188), not significant in right ventricle ($P = 0.0632$). The differences in number of positive cells between infarct and non-infarct (disregarding the group the cases belonged) was highly significant particularly in the posterior left ventricular wall ($P = 0.00005$), but also in the lateral left ventricular wall ($P = 0.0023$) and in the right ventricular wall ($P = 0.0088$) (Table 3).

If we accept that CD15 positive cells increase in the infarcted tissue with time after the onset an infarct, we can rank the

Table 2 Presence and localization of acute and healed ventricular myocardial infarcts

Type of lesion	**Coronary group (15 cases)**				**Non-coronary group (15 cases)**			
	Left ventr.			Right ventr	Left ventr.			Right ventr
	Ant	*Post*	*Lat*		*Ant*	*Post*	*Lat*	
Acute infarct								
Macroscopic examination	2	9	0	1	0	0	1	1
Microscopic examination	12	13	13	6	4	3	3	0
Myocardial scar								
Macroscopic examination	4	11	5	0	2	4	2	0

Differences between frequency of acute infarcts in the two groups:
Macroscopic examination:
Anterior wall: $P = 0.48$ Lateral wall: $P = 1.0$
Posterior wall: $P = 0.0007$ Right ventricle: $P = 1.0$
Microscopic examination:
Anterior wall: $P = 0.0092$ Lateral wall: $P = 0.00015$
Posterior wall: $P = 0.0025$ Right ventricle: $P = 0.017$
Differences between frequency of macroscopic scars in the two groups:
Anterior wall: $P = 0.65$ Lateral wall: $P = 0.39$
Posterior wall: $P = 0.027$

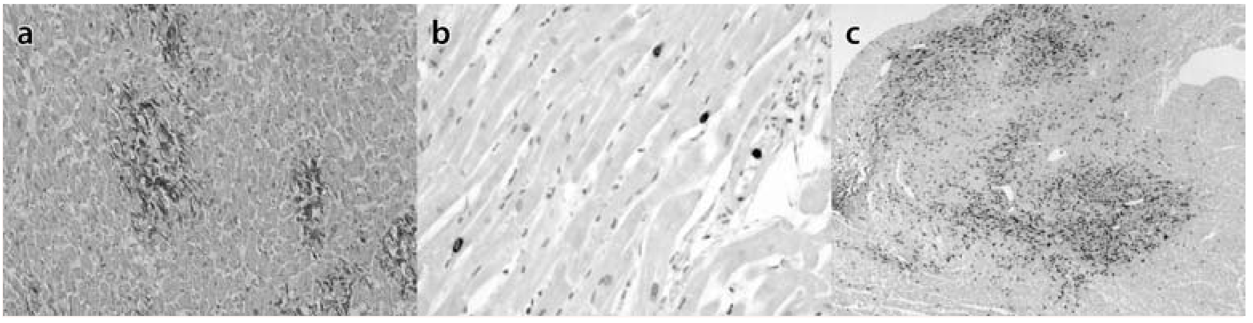

Fig. 2 Myocardial infarct stained with C9. The infarcted area is continuous, but the staining with C9 is spotty (×250) (**a**). (**b**) and (**c**) other infarcted areas stained with CD15 (**b**) from a fresh infarct with few positive cells (×450); (**c**) from an infarct of several hours duration with numerous positive cells (×180).

infarcted areas in each case according to their age at time of death (Table 4). It is obvious that the infarcts had arisen early in the posterior wall in the majority of the cases: 10 of 13 in the coronary group and four of seven in the non-coronary group.

The estimated maximum degree of atherosclerotic stenosis in the three main coronary arteries is shown in Table 5. In all three arterial stems the degree of arterial stenosis was greater in the coronary group than the non-coronary group. Only in the left descending branch did this difference reach statistical significance ($P = 0.013$).

The various forms of acute lesions in the coronary arteries are illustrated in Figures 3 and 4; ruptured necrotic plaque, with or without intraplaque haemorrhage and thrombosis, was most frequently found (Table 6). In the coronary group the acute lesions

Table 3 Number of CD15$^+$ cells in sections from four different cardiac areas

	Infarct present				No infarct present			
No. of CD15$^+$ cells	Left ventr.			Right vent	Left venr.			Right vent
	Ant.	*Post.*	*Lat.*		*Ant..*	*Post.*	*Lat.*	
Coronary group								
0 – 9	0	0	0	1	1	1	1	6
10 – 19	4	4	4	4	2	1	1	2
20 – 29	7	3	7	0	0	0	0	0
>30	1	6	2	1	0	0	0	1
Total	12	13	13	6	3	2	2	9
Non-coronary group								
0 – 9	2	0	0	0	4	8	7	12
10 – 19	2	2	2	0	5	1	4	2
20 – 29	0	1	0	0	2	2	2	0
>30	0	1	0	0	0	0	0	0
Total	4	4	2	0	11	11	13	14*)

*) Frequency missing = 1

Difference in CD15-counts between the coronary and non-coronary group (without regard whether infarct was present or not):

Anterior wall: $P = 0.0457$
Posterior wall: $P = 0.0227$
Lateral wall: $P = 0.0188$
Right ventricle: $P = 0.0632$

Difference in CD15-counts between infarct and non-infarct (without regard to which group (coronary or non-coronary) the case belonged):

Anterior wall: $P = 0.1655$
Posterior wall: $P = 0.00005$
Lateral wall: $P = 0.0023$
Right ventricle: $P = 0.0088$

were significantly more frequent in the left coronary artery (both branches) compared to the non-coronary ($P = 0.024$ and 0.013, the circumflex and descendent branches, respectively). In the right coronary artery the difference between acute lesions in the two groups did not reach significance.

The acute lesions of the coronary arteries were probably of varying age. The age of the plaque ruptures, with or without intraplaque haemorrhage, was difficult to judge. They could be of short duration: seconds–a few minutes–before a thrombus has reached to be formed on the site. On the other hand, they may have been the former site of a thrombus, now lysed.

There were no thrombi in the circumflex branch of the left coronary artery. In the main left coronary artery and its descending branch, as well as in the right coronary artery, there were altogether 12 thrombi in 11 cases of the coronary group and one case with thrombus in the non-coronary group. They appeared to have been of varying age, from seconds to several hours (6–12 hrs) (Figs. 3B and 4, Table 7).

In the first seconds to the first minutes, the thrombotic material consists mainly of more or less densely packed platelet aggregates, with no or little fibrin and no or few polymorphonuclear leucocytes (Fig. 4A). Beyond the first minutes the age of the thrombus was estimated by the amount of fibrin present, whether there were signs of fibrinolytic activity in association with the thrombus, or whether the coagulation part of the thrombus partly adhered to the wall or not (Figs. 3B and Fig. 4B and C).

Table 6 also shows the frequency of organized thrombi (Fig. 5A) in the three coronary arterial stems. Most organized thrombi occurred in the right coronary artery. Comparing the two groups, there were significantly more organized thrombi in the right coronary artery in the coronary group than in the non-coronary ($P = 0.035$).

Fresh bleeding in the granulation tissue of organized thrombi (Fig. 5B) is included among the recent occlusion types since the acute extravasation may obstruct a remaining lumen. Age of such a fresh bleeding is difficult to estimate the first hours after it arises.

Table 4 Infarcts in multiple areas of artery supply*)
The left ventricular infarcts in the order of decreasing or equal number of CD15 counts, assumed to reflect their order of decreasing/simultaneous age at the point of death.

Coronary group	
Posterior wall > Lateral wall > Anterior wall	1
Posterior wall > Lateral wall = Anterior wall	3
Posterior wall = Lateral wall > Anterior wall	2
Posterior wall = Lateral wall = Anterior wall	2
Posterior wall = Anterior wall > Lateral wall	1
Posterior wall= Lateral wall	1
Anterior wall > Lateral wall = Posterior wall	1
Anterior wall = Lateral wall > Posterior wall	1
Lateral wall > Anterior wall > Posterior wall	1
Total cases with acute infarcts	13
Non-coronary group	
Posterior wall = Lateral wall	2
Posterior wall > Anterior wall	1
Posterior wall	1
Anterior wall	2
Lateral wall	1
Total cases with acute infarcts	7

*) The infarcts were of varying size. This table registers only the site of the infarcts.

Discussion

Material

Our main interest in this study is to examine whether and how often we could identify myocardial infarction in abruptly dying persons with coronary heart disease. In cases of established myocardial infarction we wanted to look for signs which could give some indication of the time between the onset of the infarction and the sudden death. In order to answer these questions we felt it necessary to be able to compare our findings in cases of coronary heart disease with a matching group of persons who died abruptly of other causes.

It turned out that several of the cases in the non-coronary group had significant coronary heart disease, although that was not the cause of their immediate death. We therefore felt it incorrect to change the original allocation of cases into the two groups. In fact, we thought it interesting, but not really surprising, that asymptomatic myocardial infarcts occurred in association with other dominating causes of death.

Time-related changes

In both groups we looked for any change which could have taken place in the heart during the minutes or hours before the abrupt death:

(i) by carefully searching signs of an early infarct by macroscopic examination;
(ii) by carefully looking for established signs of myocardial infarct by microscopy;
(iii) by determining C9-positive areas in the infarcts;
(iv) by counting the number of CD15 positive leucocytes in the myocardium and
(v) by observing changes in the major coronary arteries in multiple cross histological sections.

(1) *Macroscopic identification of a recent infarct* is difficult in the first 2–3 hrs. A localized, unsharp pale yellowish area in a myocardial cut surface may give suspicion of a fresh infarct. A negative nitroblue tetrazolium reaction may support the suspicion.

Most of the grossly observed infarcts were located in the posterior wall of the left ventricle in cases of the coronary group. This could mean that the posterior wall infarcts, supplied by the right coronary artery, were older than infarcts in the other fields of arterial supply.

(2) *Microscopic identification of recent infarcts* is dependent on the recognition of disturbed muscular cross striation in the microscope. Additional features are reactive changes in the supporting tissue in the form of oedema and hyperaemia. According to our experience these phenomena are apparent within 1 or 2 hrs [30–32].

(3) *Development of C9 positivity* of the contractile cells is, in the present study, a late, somewhat variable phenomenon. It was not uncommon that the positive cells were found in only smaller parts of the infarcts, perhaps the oldest parts of the infarct?

(4) *Increasing accumulation of CD15* positive cells in the infarcted tissue with time after the infarction. The majority of the CD15 positive cells in the infarcted myocardium are polymorphonuclear leucocytes, perhaps also a minor portion of monocytes as well [18–20]. The accumulation of polymorphonuclear leucocytes in the myocardium is a response to reperfusion injury of the tissue and takes place in two stages: (i) accumulation of leucocytes in the microcirculatory vessels due to adherence to the endothelial cells and (ii) invasion of the leucocytes into the tissue [33, 34]. With the magnification used when counting the cells we were unable to differentiate sharply between the intra- and extravascular location of the CD15 positive cells.

The number of CD15 positive cells in the myocardium is probably the most reliable measure of the age of an infarct since the accumulation of neubrophil polymorphonuclear leucocytes into the infarcted myocardium shows a linear relationship with time [22].

Conventionally, it is stated that infiltration of the polymorphonuclear leucocytes in the myocardial tissue is well developed at 6 hrs, a statement also put forward by a report of a WHO Scientific group [35]. In man, the first intracapillary polymorphonuclear leucocytes appear during cardiac surgery just following 20 min. of reperfusion

Table 5 Maximum degree of stenosis in coronary arterial stems

Estimated per cent of stenosis	Coronary heart disease group (15 cases)			Non-coronary sudden death group (15 cases)		
	L.circ	*L.desc*	*Right*	*L.circ*	*L.desc*	*Right*
0	1	0	1	6	1	2
<25%	1	0	0	0	7	3
25%<50%	2	2	2	4	2	5
⩾50%<75%	6	10	6	5	5	4
⩾75%<90%	3	3	4	0	0	1
⩾90%<100%	2	0	2	0	0	0

Difference between groups:
Left circ. $P = 0.066$
Left desc. $P = 0.013$
Right $P = 0.117$

Table 6 Acute and healed lesions in the coronary arteries

Type of lesion	Coronary group			Non-coronary group		
Acute lesions:	***L.circ***	***L.desc***	***Right***	***L.circ***	***L.desc***	***Right***
Ruptured plaque, uncomplicated	0	2	0	0	1	0
Ruptured plaque, with haemorrhage	4	4	3	0	0	3
Ruptured plaque, with thrombus	0	3	4	0	0	1
Recent thrombus without ruptured plaque	0	1	3	0	0	0
Haemorrhage in or–ganized thrombus	2	0	1	0	0	1
No acute arterial lesion	9	5	4	15	14	10
Old lesions:						
Organized thrombus	4	1	7	0	0	1

Difference between the acute lesions in the two groups:
Left circ. $P = 0.024$
Left desc. $P = 0.013$
Right $P = 0.1065$
Difference between the old lesions:
Left circ. $P = 0.032$
Left desc. $P = 1.00$
Right $P = 0.035$

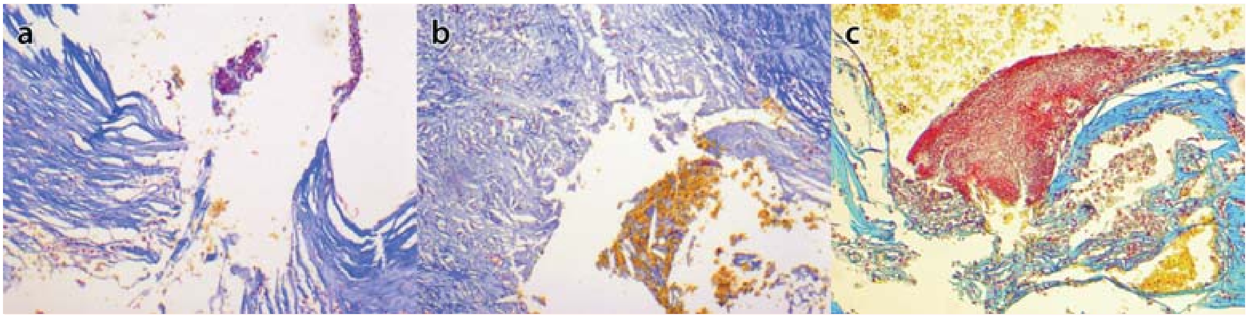

Fig. 3 Coronary arteries with ruptured necrotic plaque. (**a**) Ruptured plaque with a small amount of reddish material on the lip of the left lip of the rupture site. Probably a recent lesion (×450). (**b**) Ruptured plaque with a small mural thrombus, rich in fibrin (stained red). Probably a thrombus of several hours (×450). (**c**) Haematoma in a ruptured plaque, probably quite recently arisen (×450). Lendrum stain.

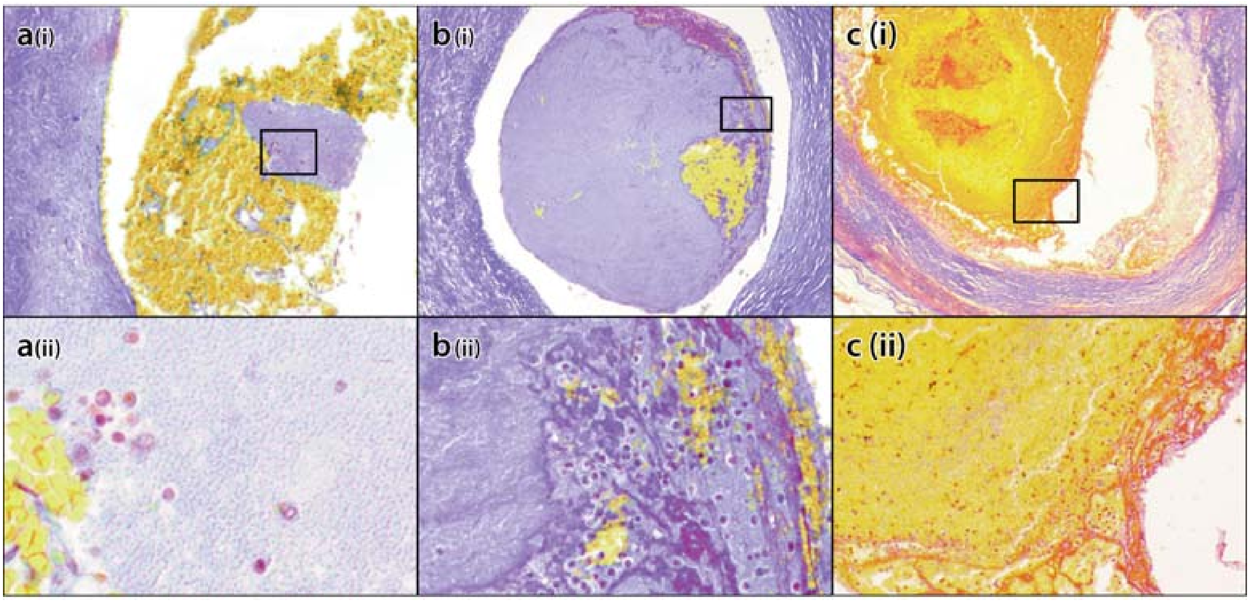

Fig. 4 Three thrombi without ruptured plaque of varying type and age. (**ai**) Freely floating platelet aggregate at an arterial stenosis (×450). (**aii**) Larger magnification showing that the thrombus is a fresh platelet aggregate with a few reddish blue leucocytes and without fibrin. It may have formed seconds or a few minutes ago in disturbed flow at the stenosis. Alternatively, it could be an embolic platelet aggregate broken off an upstream thrombus. We did not, however, observe another thrombus in the same artery (×880). (**bi**) Another apparently freely floating thrombus nearly filling the entire lumen. It is composed of densely packed platelets framed with a varying thick fibrin membrane (×250). Larger magnification in (**bii**) shows the fibrin membrane with trapped red and white blood cells. This thrombus is several minutes of age, hardly more than 0.5 hr (×450). (**ci**) A coagulation part of an estimated thrombus with red blood cells trapped in a fibrin net and surrounded by a well-developed fibrin membrane (×250). (**cii**). To the left the thrombus is adherent to the intima, to the right a slit of open lumen. The thrombus is probably several hours of age (×450). Lendrum stain.

after induced myocardial ischaemia with cardioplegia, lasting a little more than an hour [36].

With the methodology used, values between zero and 20 were compatible with an unchanged myocardium or a recently developed infarct. CD15 positive counts between 20 and 30 gave suspicion of an infarct-related abnormal value, whereas a count of 30 or more may be compatible with an established infarct of more than a couple of hours up to 5–6 hours.

Our criteria for the diagnosis of myocardial infarct did not include the presence of polymorphonuclear leucocytes.

Since only a minority of the observed infarcts had increased amount of leukocytes we suspect that they begun to became arrested in the microcirculation shortly after the histological signs of the ischaemic necrosis had taken place. We suspect that most of the initial delay of the appearance of the leucocytes is due to a prolonged initial ischaemia.

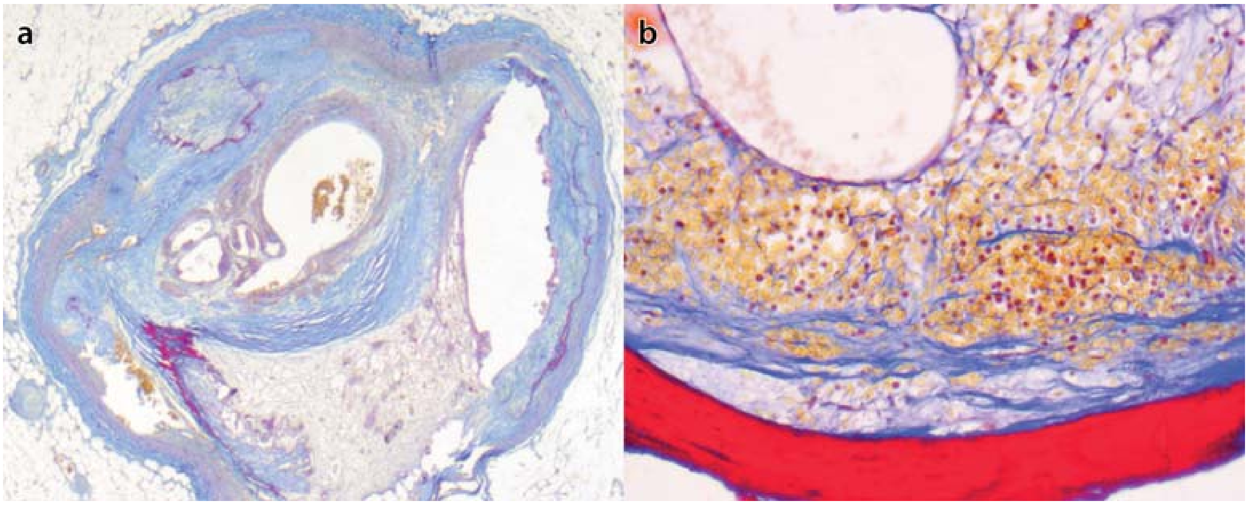

Fig. 5 From two organized thrombi with granulation tissue and multiple blood channels. (**a**) Overview of a typical organized thrombus with red calcified deposits (×120). (**b**) Detail of another organized thrombus. In the granulation tissue extravasated red blood cells as a sign of interstitial bleeding. The red-stained structure at the bottom is a calcium deposit in the tissue (×880). Lendrum stain.

Table 7 Estimated duration of a total of 12 thrombi*) in the coronary arteries of 11 cases

	Coronary group			Non-coronary group		
	Few min.	<1 h>	1 h	Few min.	<1 h>	1 h
Ruptured plaque with thrombus	1	1	4	0	1	0
Thrombus without rupture	1	1	3	0	0	0
Total	2	2	7	0	1	0

*) Eight in right coronary artery, four in ramus descendens of left coronary artery.

(5) *Acute changes in the coronary arteries* were registered and categorized according to Jørgensen *et al.* [22] who in a previous autopsy study reported artery changes in of acute coronary deaths.

Ruptured necrotic plaque with or without intraplaque haemorrhage may be considered an abrupt change, probably of short standing, but we cannot exclude a former lysed thrombus at the site, which would mean that the lesion had been of longer standing. Development of a mural or occluding thrombus secondary to a ruptured necrotic plaque was considered to be a complication which had to take some time, particularly if the thrombus had become large or rich in fibrin.

Other types of thrombi were observed at sites of stenosis without a rupture or even without an intimal attachment. These thrombi varied from fresh unattached or loosely attached platelet aggregates with no or little fibrin to occluding mixed platelet aggregate-coagulation thrombi. Since thrombi follow a certain pattern of change during the first minutes and hours [23–26], their age may be roughly estimated. In the present material a minority of them appeared to have existed only seconds, a few minutes or less than an hour, most probably shorter than observable infarcts.

The question may be asked whether such unattached or loosely attached thrombi are reversible, perhaps repeating and formed within the flowing blood at arterial stenoses, as described by Folts *et al.* [37, 38]. In fact, platelet aggregates have been found as microemboli in downstream epicardial and intramyocardial arteries in cases of sudden coronary death [39–41]. Experimentally, embolism with platelet aggregates in the myocardial microcirculation may alone cause infarction [30, 42].

Acute coronary lesions without infarct

Two cases in the coronary group had ruptured necrotic plaques, but no myocardial infarct could be diagnosed. In one of them the rupture was complicated by an occluding fresh platelet aggregate in a small remaining lumen.

Infarcts without acute coronary lesion

In one case in the coronary group and in four cases in the non-coronary group we found myocardial infarct, but no acute arterial occluding process. The explanation may be that we have overlooked an acute change or that the thrombus had been of the reversible type described above. Alternatively, the ischaemia could be the result of coronary artery spasm [44].

Predominance of right coronary artery

The most remarkable observation in the coronary group is the predominance of pathology in the right coronary artery and its area of supply, the posterior left ventricular wall. Judged by highest number of CD15 positive counts in the infarcted myocardium and the visibility of the infarcts by macroscopic diagnosis, the earliest infarcts usually included the posterior wall. The majority of ventricular scars following previous infarcts were also located in the posterior wall. Many of the acute coronary lesions were located in the right coronary artery and the organized thrombi were particularly found in the distal part of the right coronary artery. In another paper on abrupt coronary death we observed signs of spasm post mortem in the distal part of the right coronary artery [43].

The affections of right coronary artery and its area of supply, the posterior wall, may cause a particular predisposition for an abrupt death due to acute ischaemia of central parts of the heart conducting system in patients with recent asymptomatic myocardial infarction.

Infarcts in the non-coronary group

The acute myocardial infarcts in the seven cases belonging to the non-coronary group were judged to be less extensive than the infarcts in the coronary group. The majority of the non-coronary cases had, however, well-developed coronary atherosclerosis. In the four cases of suicide by shooting themselves a difficult life situation and planning the suicide could have precipitated a stress-induced myocardial infarction [10, 44–45]. One case which was found with a fractured skull at the bottom of a stair may have fallen as the result of an acute disturbance of the heart function.

Conclusion

In abrupt deaths due to coronary heart disease, there is usually an underlying asymptomatic myocardial infarction, of varying length of time up to several hours, first and most frequently affecting the posterior left ventricular wall, later also other arterial areas of supply. The abrupt death is probably caused by a lethal arrhythmia due to ischaemia of central parts of the cardiac conduction system. The infarcts in the non-coronary group are probably also asymptomatic, they were less extensive, often affecting only one arterial area of supply. In this group myocardial infarction was not the main cause of death.

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