Coronary Artery-Atrioventricular Fistula and Ventricular Septal Defect due to Penetrating Wound of the Heart

By Robert C. Jones, Lt. Col., MC, and Edward J. Jahnke, Col., MC

Although wounds of the heart have interested man from antiquity, it was not until 1896 that the first successful repair of a cardiac laceration was carried out by Rehn.1 By 1958 with the advent of modern diagnostic and surgical technics there were many comprehensive reports of penetrating heart wounds with survival (cited by Parmley et al.2).

In civilian practice the majority of such penetrating wounds are inflicted by the knife or ice pick. As seen in military hospitals they are more commonly due to bullets or shell fragments. The usual residual defects, in approximate order of frequency, are laceration of the wall of the heart, defect of the ventricular septum, and fistulous connection between the root of the aorta and right ventricle, or between aorta and right atrium. Laceration of a coronary artery or damage to heart valves can also occur. Constrictive pericarditis has been reported but is rare.3

In a recent publication, Summerall et al.4 could find only 12 reported instances of a residual intracardiac shunt due to a penetrating wound of the heart. They reported two additional patients, one of whom was unique in that there was a fistula between the left ventricle and coronary sinus. The purpose of this presentation is to direct attention to another combination of lesions not previously reported in the literature.

Case Report

On October 4, 1964, an 18-year-old soldier was accidentally wounded in the chest at close range by a .38 caliber bullet fired from a pistol. He was immediately transported to a nearby military hospital where resuscitative measures for profound shock were carried out while preparations were being made for thoracotomy. As seen at surgery the wound of entry was in the fourth left intercostal space 5 cm. lateral to the midsternal line. The bullet entered the left ventricle, anteriorly damaging the anterior descending coronary artery. It emerged from the heart on the right side at the junction of the inferior vena cava with the right atrium, where it had produced an extensive laceration approximately 6 cm. in length. The bullet came to rest in the right upper lobe of the liver. The laceration at the point of exit from the heart was repaired by suture. A pericardial patch was applied at the point of entrance over the left ventricle, rather than direct suture, in an effort to prevent further compromise of the damaged coronary vessels.

After repair of the heart, palpation revealed a thrill over the right atrium and right ventricle. This was believed to represent a posttraumatic ventricular septal defect and possible damage to the tricuspid valve. When the patient's condition was stable, he was transferred to Walter Reed General Hospital for further management.

As of October 28, 1964, (at WRGH) he was relatively asymptomatic and had good exercise tolerance. Pertinent physical findings included a normal jugular venous pulse and absence of pulsations over the liver, thus suggesting that significant traumatic tricuspid insufficiency was not a problem. The peripheral arterial pulse and blood pressure were normal, denying the presence of a large systemic arteriovenous communication. Absence of overactivity of the heart, lack of cardiomegaly, and no precordial thrill militated against a significant ventricular septal defect. There was a grade-III/VI systolic and I/VI diastolic murmur of maximum intensity in the second and third intercostal space at the right sternal edge. The systolic component of the murmur seemed to extend beyond the second heart sound similar to that heard in patent ductus. The diastolic component was short, did not extend throughout diastole, and was abolished after inhalation of amyl nitrite. (In subsequent weeks the murmur grew progressively louder to become a grade-IV/VI continuous machinery murmur associated with a pronounced chest-wall thrill, overactive heart, and brisk arterial pulse.) The electrocar-

From the Cardiology and the Thoracic and Cardiovascular Surgery Services, Walter Reed General Hospital, Washington, D. C.

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diagram on the day of injury demonstrated evidence of inferior and posterior myocardial infarction. The chest roentgenogram revealed elevation of the right hemidiaphragm, retained missile in the upper portion of the liver, absence of pulmonary congestion, and no increase in heart size compared to the normal pre-accident films.

Based on clinical observations, the character of the murmur, and the operation report from initial thoracotomy, arteriovenous fistula, possibly involving the left coronary artery, was suspected. The additional presence of a small defect in the interventricular septum could not be excluded.

At right heart catheterization on November 18, 1964, there was a consistent and sudden increase of 7 per cent in oxygen saturation at the level of the low right atrium. The inferior vena cava was not entered, so that more precise localization of the shunt or assessment of the pulmonic/systemic flow ratios was not possible by this method. The following pressures expressed in mm. Hg were recorded: RA—mean 10, a = 13, v = 12.5; RV = 25 with elevated end-diastolic pressure to 10-12; PA = 25/12. A platinum electrode catheter study utilizing inhaled hydrogen gas as the indicator substance was then carried out. The arrival time of indicator was 11 seconds in the SVC, 9.5 in high RA, 3.5 in low RA, and 3.7 in RV and pulmonary artery.

Retrograde aortograms were interpreted as showing sudden termination of a greatly dilated coronary artery in the floor of the right atrium. The left main coronary artery filled but appeared to be reduced in diameter in its distal half. Near the apex it filled in an antegrade manner but carried very little contrast media (fig. 1). In March 1965 selective coronary arteriography was performed by Dr. Richard Ross at Johns Hopkins Hospital in an attempt further to delineate the lesion and to ascertain the integrity of the distal coronary circulation. Unfortunately, the left coronary could not be engaged because of the “selective torrential flow through the right coronary.” However, these cineangiograms confirmed the presence of a communication between the right coronary artery and the floor of the right atrium. Left ventriculograms did not demonstrate the ventricular septal defect that was found at surgery. It appeared that the right coronary artery had enlarged to a significant extent in the intervening 4-month period since the original retrograde aortogram.

Exercise stress tests performed at WRGH and Johns Hopkins Hospital revealed no ischemic changes on the postexercise electrocardiogram. The patient remained relatively asymptomatic, except for mild fatigue on ordinary exertion and mental concern over the fact that he had some-thing wrong with his heart. In May 1965 surgical correction was undertaken.

Operative Report

The heart was exposed through a right anterior thoracotomy incision. The right coronary artery was massive in size, measuring approximately 18 mm. in diameter throughout its entire length. A soft systolic thrill was palpable over the lower portion of the right atrium. Palpation through the right appendage revealed a forceful jet of blood entering the right atrium just distal to the coronary sinus and on the atrial side of the commissure between the medial and posterior leaflets of the tricuspid valve. This was believed to represent the fistulous connection between the right coronary artery and the right atrium.

Employing a disposable plastic bag oxygenator primed with 2,000 ml. of 5 per cent glucose in 0.2 per cent normal saline, cardiopulmonary bypass was begun. A long right atriotomy incision, parallel to the atroventricular groove, was employed. Inspection within the right heart revealed a large jet of arterial blood coming from the region of the fistula previously described. In addition, copious quantities of arterial blood were jetting back from the right ventricle. By temporary external compression of the right coronary artery it could be ascertained that there were two components to the fistula. One opening of the right coronary fistula was into the right atrium just proximal to the commissure between the medial and posterior leaflets of the tricuspid valve. This defect was elliptical and measured approximately 1 cm. in length. The second fistulous connection was between the right coronary artery and the right ventricular cavity just distal to the tricuspid valve and slightly behind the posterior leaflet of that structure. This defect was also elliptical in shape and approximately 1.5 cm. in length. Both defects were closed with interrupted sutures of vascular silk, which were then reinforced by a second over-and-over continuous suture of similar material (fig. 2). Care was taken to avoid obliteration or compromise of the right coronary lumen.

Following complete closure of these defects additional inspection within the right ventricle revealed a persistent jet of arterial blood coming from the interventricular septum in the region of the outflow tract. This proved to be a small ventricular septal defect, presumed traumatic, just caudal to the insertion of the papillary muscle of the conus. It was circular and measured approximately 5 mm. in diameter. Complete closure was obtained with two mattress sutures of vascular silk. Final inspection now revealed absence of bright blood appearing on the right side of the heart. The atriotomy incision was closed and bypass discontinued after all the contents of the
penetrating wound of the heart

A plastic bag oxygenator had been drained into the patient's vascular system. Repeat intraatrial palpation confirmed the complete closure of the fistulas and ventricular defect by the absence of any evidence of a jet of blood as noted prior to repair.

The left coronary artery was not directly visible at surgery. Its blood flow was considered to be adequate in view of the fact that no serious electrocardiographic or hemodynamic consequences ensued during periods of repeated clamping of the main right coronary artery during repair of the fistula. There were no significant electrocardiographic changes in the postoperative period to suggest myocardial ischemia or additional infarction.

Routine chest closure was performed and underwater tube drainage was utilized. The early

Figure 1

Biplane retrograde arteriograms. Left upper. Prominent right coronary which suddenly terminates; poor filling of left coronary. Note bullet below right diaphragm. Right upper. Right coronary artery emptying into floor of right atrium with "sprinkling can" appearance. Left lower. Schema showing fistula and visualization of small anterior descending coronary artery. Right lower. Magnified view demonstrating anatomic course and minimal contrast material in anterior descending coronary artery.
postoperative course was uneventful and no heart murmurs could be detected on careful auscultation. During the third postoperative week a grade I/VI systolic murmur along the right sternal edge was detected. In the fourth postoperative week the systolic murmur became grade II/VI and a diastolic component was audible. It was suspected that partial breakdown of the surgical repair had occurred. Three months after surgery the patient was asymptomatic but because of heart murmurs similar to those heard in the preoperative period hemodynamic studies will be repeated, contingent on the consent of the patient, to assess any residual pathology.

Discussion

The decision for corrective surgery in this patient was carefully weighed. There was no precedent set in the literature regarding coronary artery-atrial fistula with one possible exception. A probable similar case was reported by Parmley et al.\textsuperscript{2} in 1958. Their patient was wounded by shell fragments in Korea in 1950, was treated for hemothorax and returned to full military duty. Two years later on a re-enlistment physical examination a continuous precordial murmur was heard. At catheterization at WRGH in 1952 a left-to-right shunt at the atrial level with pulmonic systemic flow ratio of 2.3:1 was noted. Retrograde aortograms performed at the National Heart Insti-
tute were similar to ours. Surgery was recommended but refused by the patient. From personal communication, this patient is still alive, working full time and relatively asymptomatic 12 years later.

Since operating on this patient we have learned of two additional cases of coronary artery-atrial fistula due to gunshot wound of the chest. Blake et al.\textsuperscript{6} have successfully repaired such a lesion and are probably the first to do so. Another patient with a similar lesion will be reported by Tsagaris and Bustamante.\textsuperscript{7}

Our decision to proceed with surgery was based partly on the progressive nature of the lesion. Under observation, the diastolic component of the murmur increased and a chest-wall thrill developed. The peripheral arterial pulses became quite brisk. A significant increase in size of the right coronary artery was visualized during the 4-month period between angiographic studies.

Other considerations were discussed. There was electrocardiographic evidence of myocardial infarction with poor evidence of adequate collateral coronary flow by arteriographic studies. Since the natural history of virtually all acquired systemic AV communications is that they enlarge with time, it was presumed that run-off into the low-pressure right atrium might progressively reduce the blood supply to the myocardium. Even in the congenital variety of coronary AV fistula there are some who believe that the long-term outlook for such patients is improved by surgical intervention, even though the lesion may be tolerated for many years.\textsuperscript{8} The possibility that bacterial endarteritis or endocarditis might supervene was another factor. In the opinion of some this latter reason by itself might be sufficient justification for surgical intervention.\textsuperscript{9, 10}

The question regarding the presence of a posttraumatic ventricular septal defect had to be answered, since the position of the thoracotomy incision would be influenced by this. The estimated path of the missile suggested that it did traverse the interventricular septum. Whether the defect had closed spontaenously or whether we had failed to demonstrate it on two separate studies was a matter for conjecture.

From experimental studies in dogs Griffin and Essex\textsuperscript{11} and Kay et al.\textsuperscript{12} demonstrated spontaneous healing within 2 to 5 months of surgically created ventricular septal defects up to 10 mm. in diameter. Walker\textsuperscript{13} reported spontaneous closure of such a lesion in the human 10 years after shell-fragment wounds of the heart.

Based on total clinical and hemodynamic studies we thought we had excluded the presence of posttraumatic ventricular septal defect. Our observations gave us no clue to the fact that the coronary fistula also communicated with the right ventricle. At the time of surgery it was possible to repair all the defects via the right atriectomy incision by retracting the leaflets of the tricuspid valve.

In view of the probable partial recurrence of the fistula 3 weeks after apparent successful repair, the alternate surgical procedure of choice might have been to ligate the main right coronary artery, at its point of communication with the cavities of the heart. In this instance we were reluctant to do this because of previous visual and electrocardiographic evidence of damage to the left coronary artery.

**Summary**

A patient with an unusual combination of lesions secondary to gunshot wound of the heart is presented. The predominant abnormality was a large fistula between the right coronary artery and the floor of the right atrium. The right coronary also communicated with the cavity of the right ventricle, and there was an associated posttraumatic ventricular septal defect. The presence of an arteriovenous fistula was suspected, based on the presence of a continuous precordial murmur. This diagnosis was confirmed by arteriography. Findings at surgery and the technic of repair are illustrated. Reference is made to three other patients with traumatic communication between the coronary artery and the atrium. Attention is directed to coronary artery atrioventricular fistula as another anatomic type.
of deformity to consider in patients with penetrating wounds of the heart. The probable recurrence of the fistula 3 weeks after what appeared to be a successful repair illustrates one of the problems to consider in evaluating such patients for surgery.

Acknowledgment

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Addendum

Repeat cineangiogram on this patient in September 1965 revealed a recurrence of his right coronary-right atrial fistula. The residual or recurrent fistula was smaller than that initially observed. It was decided that further operative intervention would be undertaken to close the fistula completely.

On October 14, 1965, the patient was reoperated upon and the right hemithorax entered through the site of the previous thoracotomy. Palpation within the right atrium revealed a residual soft jet of blood into the right atrium at the site of the previously repaired fistula. The right coronary artery was dissected free proximal and distal to this site. The coronary artery was then doubly ligated with heavy silk, both proximal and distal to the fistula. This completely obliterated the jet of blood into the atrium. The chest was closed in the usual manner. There was no interference with the cardiac rhythm or alteration of the electrocardiogram by ligation of the right coronary artery at the fistula site.

References

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The Endless Chain

To succeed in science it is necessary to receive the tradition of those who have gone before us. In science, more perhaps than in any other study, the dead and living are one.—Charles Singer.
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ROBERT C. JONES, LT. COL. and EDWARD J. JAHNKE, COL.

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