
Cardiac Missiles

A Review of the Literature and Personal Experience

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The management of retained missiles in the heart is still controversial. In an attempt to define the issue more clearly, the reported cases in the English literature from 1940 to 1988 (group 1) and our experience from 1968 to 1988 (group 2) were reviewed. In group 1 there were 222 missiles retained in the hearts of 201 patients. The retained missiles were 45 bullets in 45 patients, 109 shrapnel in 99 patients, 18 pellets in 7 patients, and 50 unidentified missiles in 50 patients. Thirteen of the missiles were completely embedded intramyocardial missiles, 122 were partially intramyocardial, 47 were free in a cardiac chamber, and 40 were intrapericardial. One hundred four of the missiles were removed and 118 were left in place. In group 2 there were 24 missiles, 18 bullets, 1 bullet fragment, and 5 pellets retained in the hearts of 24 patients. Ten missiles were removed, no attempt was made in 13 patients, and an unsuccessful attempt was made to remove one other. From group 1 patients, 6 died, 2 with intracavitary missiles, 3 patients with partially intramyocardial, and 1 patient with an intrapericardial missile, all of whom had either unsuccessful or no attempt to remove the missile. Twenty-seven patients had symptoms, all of whom, except two, had either unsuccessful or no attempt to remove the missile. All group 2 patients did well and had been free of symptoms related to the missiles. This review suggests that the management of missiles in the heart should be individualized according to the patient's clinical course, the site, shape, and size of the missile, and that in selected patients missiles in the heart are tolerated well.

THE MANAGEMENT OF retained missiles in the heart and pericardium is still controversial.¹⁻⁵⁷ This may be due to the limited number of patients seen by each investigator, to the different chronologic period that the patients were treated and followed, and finally to the difference of the retained missiles (bullets, shrapnel, or pellets, and so on). To more clearly define the man-

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agement of cardiac missiles, the reported cases in the English literature from 1940 to 1988 and our experiences from 1968 to 1988 with such foreign bodies were reviewed.

Materials and Methods

For the purpose of the study, missiles were defined as bullets, pellets, and shrapnel secondary to bullets, mortars, and grenades or mines. Unidentified missiles included those that, from the published information, could not be further differentiated. The results from the treatment of the retained missiles were analyzed according to the type and the site of the missile and according to the type of management.

The retained missiles in the heart were divided into two groups. Group 1 includes all reported cases from 1940 to 1988 that we could find from the search of the English literature and group 2 consists of all cardiac missiles seen at Grady Memorial Hospital from 1968 to 1988.

In group 1 there were 222 missiles retained in the heart in 201 patients.¹⁻⁵⁶ Several patients had more than one missile in the heart or pericardium, including one who had 11 pellets.

In 174 patients the retained missile resulted from a direct injury to the heart or pericardium and in 27 from injury to a vein with subsequent embolization to the heart. In 22 patients a systemic vein was injured and the missile migrated to the right atrium or ventricle. In one patient a pulmonary vein was injured and the missile moved to the left ventricle, and in four patients the site of missile entry into the circulatory system was not identified.

There were 45 bullets retained in 45 patients, 109 shrapnel in 99 patients, 18 pellets in 7 patients, and 50

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TABLE 1. Sites and Management of Group 1 Cardiac Bullets

Sites (No.)	Bullets		
	Removed	Attempted to Remove	No Attempt to Remove
Intramyocardial (2)	—	1 (S)	1 (RV)
Partial Intramyocardial			
Known location (15)	3 (LV)	1 (S), 1 (RA)	4 (RV), 3 (LV), 2 (S), 1 (RA)
Unknown location (2)	—	1	1
Intracavitary			
Known location (21)	16 (RV), 2 (LV), 1 (RA)	—	1 (RV), 1 (LV)
Unknown location (2)	2	—	—
Intrapericardial (3)	3	—	—
Total (45)	27	4	14

RA, right atrium; RV, right ventricle; S, ventricular septum; LA, left atrium; LV, left ventricle.

unidentified missiles in 50 patients (Tables 1 to 4). Two of the retained bullets were completely embedded in the myocardium (1 in the right ventricular and 1 in the septal, 17 were partially embedded in the myocardium, (6 in the left ventricular, 4 in right ventricular, 3 in the septal, and 2 in the right atrial myocardium; in 2 the exact location was not described), 23 were in a cardiac cavity (17 in the right ventricular, 3 in the left ventricular, and 1 in the right atrial cavity; in 2 the cavity in which the bullet resided was not specified), and 3 bullets resided in the pericardial space (Table 1).

Ten shrapnel were described to be completely embedded in the myocardium (5 in the right and 3 in the left ventricular myocardium, and 2 in the septum), 81 partially embedded in the myocardium (22 in the right ventricle, 22 in the left ventricle, 8 in the right atrium, 3 in the left atrium, and 6 in the septum; the exact site for 20 shrapnel was not described), 7 were in a cardiac cavity (6 in the right ventricle; in 1 the exact site where the shrapnel resided was not mentioned), and 11 were in the pericardium or pericardial space (Table 2).

One of the pellets was completely embedded in the right ventricular myocardium, 4 were partially embedded in

the myocardium (2 in the left ventricle, 1 in the right ventricle, and 1 in the septum), and 13 pellets were in a cardiac chamber (1 in the right ventricular cavity and 7 in the left ventricular cavity, 1 in the right atrial cavity, and 4 in the left atrial cavity) (Table 3).

Twenty unidentified missiles were partially embedded in the myocardium (7 in the right ventricle, 5 in the left ventricle, 6 in the right atrium, and 2 in the septum), 4 were in a cardiac cavity (1 in the left ventricular cavity; in 3 the cavity in which the missile resided was not stated), and 26 were in the pericardial space (Table 4).

Twenty-seven of the retained bullets were removed, 4 had unsuccessful attempts to remove them, and in 14 no attempt at removal was made (Table 1). Twenty-two retained shrapnel were removed, 16 had unsuccessful attempts to remove them, and in 71 no attempt to remove them was made (Table 2). Fourteen of the pellets were removed and 4 were left undisturbed (Table 3), while 41 of the unidentified missiles were removed and 9 were left undisturbed (Table 4).

Therefore from the 222 retained missiles in group 1 patients, 104 were removed. Fourteen were removed in 4 patients during emergent thoracotomy up to 2 days after

TABLE 2. Sites and Management of Group 1 Shrapnel

Sites (No.)	Shrapnel		
	Removed	Attempted to Remove	No Attempt to Remove
Intramyocardial (10)	—	—	3 (LV), 2 (S), 5 (RV)
Partial Intramyocardial			
Known location (61)	5 (RV), 3 (LV), 2 (S), 1 (LA), 1 (RA)	2 (RV), 6 (LV), 2 (S), 1 (LA)	15 (RV), 13 (LV), 2 (S), 7 (RA), 1 (LA)
Unknown location (20)	—	4	16
Intracavitary			
Known location (6)	4 (RV)	—	2 (RV)
Unknown location (1)	—	—	1
Intrapericardial (11)	6	1	4
Total (109)	22	16	71

RA, right atrium; RV, right ventricle; S, ventricular septum; LA, left atrium; LV, left ventricle.

TABLE 3. Sites and Management of Group 1 Pellets

Sites (No.)	Pellets	
	Removed	No Attempt to Remove
Intramyocardial (1)	—	1 (RV)
Partial Intramyocardial (4)	1 (S)	1 (RV), 2 (LV)
Intracavitary (13)	1 (RV), 1 (RA), 4 (LA), 7 (LV)	—
Total (18)	14	4

RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle.

injury for the treatment of cardiac or thoracic wounds, 8 during urgent thoracotomy up to 2 days after injury (6 to prevent complications and 2 for arrhythmias), and 1 during right ventricular catheterization 2 days after injury. Thirty missiles were removed later than 2 days after injury because of pericarditis in 4, complaints of pain in 5, local infection in 3, cardiac neurosis in 1, and required operation for associated thoracic injuries in 2. In 15 others no reason for removal was given except for their presence in the heart. The time of removal of 51 other missiles was not specified. Of these missiles 29 were removed solely because of their presence in the heart, 1 each because of arrhythmia, pericarditis, stroke from a clot embolus, endocarditis, and pain. In 17 patients the rationale for removal of the missile was not reported.

An attempt was made to remove 20 missiles, but it was unsuccessful because of inability to find or retrieve the missile in 12, intraoperative instability in 3, intramyocardial or encapsulated position of the missile in 3; in 2 the reason for the unsuccessful attempt was not stated. The reasons for the attempt to remove these missiles was because of required operation for thoracic injury in 8, solely because of the presence of the cardiac missiles in 1, cardiac neurosis in 1 other; in 10 the reason for the attempt to remove the missile was not stated.

No attempt was made to remove the other 98 missiles, including 3 in which emergency thoracotomy was per-

TABLE 4. Sites and Management of Unidentified Group 1 Missiles

Sites (No.)	Unidentified Missiles	
	Removed	No Attempt to Remove
Partial Intramyocardial (20)	5 (RV), 3 (LV), 3 (RA), 1 (S)*	2 (RV), 2 (LV), 1 (S), 3 (RA)
Intracavitary		
Known location (1)	—	1 (LV)
Unknown location (3)	3	—
Intrapericardial (26)	26	—
Total (50)	41	9

RA, right atrium; RV, right ventricle; S, ventricular septum; S*, atrial septum; LV, left ventricle.

formed for a thoracic injury but the presence of the retained cardiac missile was not known at operation. Of the remaining 95 missiles, 17 were not removed because of their small size, 12 because of their intramyocardial location, 1 because of its inaccessible location, 10 because of lack of symptoms, 2 because the diagnosis was not made before death, 1 due to a late diagnosis of the retained missile, 1 because surgery was contraindicated for other reasons; in 51 no reasons were reported.

Group 2 consists of 24 missiles in 24 patients.⁵⁷ In 22 of them the retained missile was a result of direct trauma to the heart, while in two patients it resulted from injury to a systemic vein with subsequent migration to the heart. The retained missiles included 18 bullets, 0.38 caliber or smaller, 1 bullet fragment, and 5 pellets (Table 5).

Fifteen of the missiles were located within the heart and nine within the pericardial sac. Five of the missiles located in the heart were completely intracavitary. Three of them resulted from a direct cardiac injury (one from injury of the right inferior pulmonary vein at the junction to the left atrium) and the two others migrated to the right ventricle after injury to an iliac vein. Of the 15 heart missiles, 7 were located in the right heart, 6 in the left, and 2 within the septum.

In three patients the missile was removed because it was accessible at the time of emergent exploratory thoracotomy for cardiac tamponade or bleeding, while in seven patients it was removed electively to prevent possible future complications including pericarditis, missile embolization, clot embolization, endocarditis, or erosion of blood vessels. In another patient operated on electively with the use of cardiopulmonary bypass, the missile could not be removed safely. In no case was an operation performed specifically to remove the retained missile because of symptoms related to the missile.

Ten of the 14 missiles left in the heart were completely embedded in the myocardium (2 in the left, 6 in the right, and 2 in the ventricular septum), 2 were trapped in the right ventricular trabeculations, and 2 resided in the pericardial space (Table 5). The reasons for not attempting to remove these missiles are as follows: (1) the patients did not want to be operated on, (2) the missile could not be safely removed, or (3) it was believed to be safe to leave the missile in place.

TABLE 5. Group 2 Missiles and Their Management

Missile	Removed	No Attempt to Remove	Unsuccessful Attempt to Remove
Bullet	9	8	1
Shrapnel	1	0	0
Pellets	0	5	0
Total	10	13	1

TABLE 6. Preoperative and Postoperative Symptoms in Preoperative Group 1 Symptomatic Patients who Were Operated on Electively to Remove the Missile

Symptoms	Number of Patients	
	Preoperative	Postoperative
Pericarditis	6	—
Chest Pain	5	1
Infection	5	—
Arrhythmia	3	—
Neurosis	2	—
CVA	1	1
Total	22	2

One patient with cardiac neurosis died during operation and in 4 patients (2 with pericarditis, 1 with chest pain, and 1 with arrhythmia) the postoperative status was not stated.

Thus of the 222 cardiac missiles in 201 group 1 patients, 104 were removed from 94 patients and in the remaining 118 missiles in 107 patients either an attempt or no attempt was made to remove them. Of the 24 missiles in 24 group 2 patients, 10 were removed and 14 were left in place. The mean follow-up time for the group 1 patients who had extraction of the missile was 24.3 months (range, 74 hours to 22 years; $n = 29$) and for those who had unsuccessful or no attempt to remove them it was 195 months (range, 4 hours to 52 years; $n = 64$). The mean follow-up time for group 2 patients with the missile left in the heart was 5 years (range, 2 months to 15 years) and for those with the missile removed it was 4 years (range, 2 months to 17 years).

Results

Twenty-two of 112 patients who had extraction or attempted extraction of the missile from their heart had

preoperative symptoms (Table 6). Six had pericarditis, 5 chest pain, 5 infection, 3 arrhythmia, 2 cardiac neurosis, and 1 patient had a cerebral vascular accident. Two patients, one who had chest pain and one who had a cerebral vascular accident, continued to have symptoms after the cardiac missile was removed. The status of the symptoms after removal of the missile in four patients was not stated and the remaining 16 patients had no symptoms (Table 6).

Of the 45 bullets in the heart, one patient with a left ventricular intracavitary bullet in whom no attempt to remove the bullet was made died on the 49th day after injury from a cerebral vascular accident. Five patients had symptoms, 2 had pericarditis, 1 had chest pain, 1 cardiac neurosis, and 1 patient with a bullet in the left ventricular chamber suffered cerebral vascular accident presumably from a blood clot embolus. In all five patients no attempt to remove the bullets was made. One patient who underwent unsuccessful attempt to remove an intramyocardial missile developed a right coronary artery to right ventricle fistula. Thirty-five bullets caused no symptoms and the status of the remaining three bullets was not stated (Table 7).

From the 109 shrapnel in 99 patients there were 5 deaths. In two an unsuccessful attempt and in three no attempt was made to remove the shrapnel. One death was sudden, presumably from arrhythmia, 1 from septic emboli in a patient with a partial intramyocardial shrapnel, 1 again from sepsis in a patient with partial intramyocardial shrapnel in right ventricle, 1 from perioperative hemorrhage during unsuccessful attempt to remove shrapnel from the ventricular septum, and 1 from pericarditis and cardiac tamponade on the 11th postoperative day. Eighteen patients had symptoms. All had either no attempt

TABLE 7. Results of Management of Cardiac Group 1 Bullets

Sites (No.)	Bullets				
	Management	Asymptomatic	Not Stated	Symptomatic	Deceased
Intramyocardial (2)	1 not removed (RV)	1	—	—	—
	1 unsuccessful attempt (S)	—	—	1 (RCA, RV Fistula)	—
Partial Intramyocardial (17)	3 removed (3 LV)	3	—	—	—
	11 not removed (1 UKL, 1 RA, 3 LV, 4 RV, 2 S)	6 (1 UKL, 1 LV, 1 RV, 2 S, 1 RA)	—	5 1 CP (RV), 2 P (RV), 1 CN (LV), 1 CVA (LV)	—
	3 unsuccessful attempt (1 UKL, 1 S, 1 RA)	3	—	—	—
Intracavitary (23)	21 removed (2 UKL, 2 LV, 16 RV, 1 RA)	18	3 (1 RV, 2 UKL)	—	—
	2 not removed	1	—	—	1 CVA (LV) 49 days
Intrapericardial (3)	3 removed	3	—	—	—
Totals (45)		35	3	6	1

RA, right atrium; RV, right ventricle; S, septum; UKL, unknown location; CVA, cerebral vascular accident; RCA, right coronary artery.

TABLE 8. Results of Management of Group 1 Shrapnel

Sites (No.)	Management	Shrapnel				Deceased
		Asymptomatic	Not Stated	Symptomatic		
Intramyocardial (10)	10 not removed (3 LV, 2 S, 5 RV)	9 (6 pts; 3 LV, 1 S, 5 R)	—	1 P (S)	—	
Partial Intramyocardial (81)	12 removed (3 LV, 5 RV, 2 S, 1 RA, 1 LA)	8 (2 S, 3 RV, 2 LV, 1 LA)	3 (2 RV, 1 LV)	1 CP (RA) also preop	—	
	54 not removed (16 UKL, 13 LV, 15 RV, 2 S, 7 RA, 1 LA)	25 (22 pts; 4 RA, 11 RV, 1 S, 1 LA, 8 LV)	15 (15 UKL)	12 (9 pts) 1 P (RV) 5 CN (4 LV, 1 RA) 4 CP (3 R, 1 RV), 1 D (UKL), 1 A (RV)	1 sudden death (RV) 1 septic/embolus (LV)	
Intracavitary (7)	15 unsuccessful attempt (4 UKL, 6 LV, 2 RV, 2 S, 1 LA)	6 (5 pts; 3 LV, 1 RV, 1 LA, 1 S)	4 (4 UKL)	4 2 CP (1 LV, 1 RV) 1 CN (LV) 1P (LV)	1 perip hemorrhage (S)	
	4 removed (4 RV)	3 (3 RV)	1 (1 RV)	—	—	
Intrapericardial (11)	3 not removed (2 RV, 1 UKL)	2 (1 RV, 1 UKL)	—	—	1 sepsis (RV)	
	6 removed	4	2	3 (2 P, 1 CP)	—	
Totals (109)	4 not removed	1	—	—	1 cardiac tamponade 11 postop day	
	1 unsuccessful attempt	—	—	—	—	
	Removed =	15	6	1		
	Not removed =	37	15	16	3	
	Unsuccessful attempt =	6	4	4	2	
		58	25	21	5	

RA, right atrium; RV, right ventricle; S, ventricular septum; LA, left atrium; LV, left ventricle; UKL, unknown location; P, pericarditis; CP, chest pain; CN, cardiac neurosis; D, dyspnea; Pts, patients.

TABLE 9. Results of Management of Group 1 Cardiac Pellets

Sites (No.)	Management	Pellets			
		Asymptomatic	Not Stated	Symptomatic	Deceased
Intramyocardial (1)	1 not removed (1 RV)	1	—	—	—
Partial Intramyocardial (4)	1 removed (1 S)	1	—	—	—
	3 not removed (2 LV, 1 RV)	1 (LV)	—	2 arrhythmia (LV & RV) (1 pt)	—
Intracavitary (13)	13 removed (7 LV, 1 RV, 1 RA, 4 LA)	13 (3 pts)	—	—	—
Total (18)	Removed 14 Not removed 4	16	—	2	—

RA, right atrium; S, ventricular septum; LA, left atrium; LV, left ventricle; RV, right ventricle; Pts, patients.

or an unsuccessful attempt to remove the shrapnel, except one patient who had preoperative nonspecific chest pain also had pain after operation and successful removal of the missile (Table 8).

None of the 18 cardiac pellets in 7 patients caused death. Only one patient with two partially intramyocardial pellets, one in the left and another in the right ventricle, developed late arrhythmia (Table 9).

No deaths occurred in the category of the unidentified missiles. One patient in whom there had been no attempt to remove a left ventricular missile had a cerebral vascular accident. One patient with a partially intramyocardial missile in the atrial septum developed a cerebral vascular accident before removal of the missile (Table 10).

Considering the effects of the site of the missile on the outcome of its management, there were no deaths from the 13 intramyocardial missiles and only two patients had symptoms. One patient in whom the missile was removed developed pericarditis and one who had an unsuccessful attempt to remove the intramyocardial missile developed

coronary artery to right ventricle fistula (Table 11). Of the 122 partial intramyocardial missiles, 3 patients died, 2 from those in whom no attempt to remove the missile was made. Of those 3, 1 died suddenly, 1 from sepsis, and 1 who had an unsuccessful attempt at removal died from perioperative hemorrhage. Twenty-five patients were symptomatic, 2 patients from whom the missile was removed, 19 who had no attempt to remove the missile, and 4 with unsuccessful attempted removal (Table 11). Of the 47 patients with intracavitary missiles, two died. In both no attempt to remove the missile was made. One death resulted from a cerebral vascular accident and one from sepsis. One other patient also sustained a cerebral vascular accident. Of the 40 intrapericardial missiles, there was one death from cardiac tamponade, which occurred on day 11 after injury and an unsuccessful attempt to remove the shrapnel. Three patients had symptoms, one chest pain and two pericarditis. None had an attempt to remove the missile. Two late deaths unrelated to the retained cardiac missile occurred in group 1, one due to

TABLE 10. Results of Management of Group 1 Unidentified Cardiac Missiles

Sites (No.)	Management	Unidentified Missiles			
		Asymptomatic	Not Stated	Symptomatic	Deceased
Partial Intramyocardial (20)	12 removed (3 LV, 3 RA, 5 RV, 1 S*)	2 (1 LV, 1 RA)	9 (2 LV, 2 RA, 5 RV)	1 CVA (S*) preop	—
	8 not removed (2 LV, 2 RV, 3 RA, 1S)	8	—	—	—
Intracavitary (4)	3 removed (3 UKL) 1 not removed (1 LV)	3	—	—	—
Intrapericardial (26)	26 removed	—	26	1 CVA (LV)	—
Total (50)	Removed 41 Not removed 9	13	35	2	—

RA, right atrium; RV, right ventricle; S, ventricular septum; S*, atrial

septum; LA, left atrium; LV, left ventricle; CVA, cerebral vascular accident.

TABLE 11. Results of Management of Intramyocardial, Partial Intramyocardial, Intracavitary, and Intrapericardial Group 1 Missiles

Site	Management	Asymptomatic	Not Stated	Symptomatic	Deceased
Intramyocardial	No attempt 12	11	0	1P	0
	Unsuccessful attempt 1	0	0	1 CA → RV Fistula	0
	Total 13	11	0	2	0
Partial Intramyocardial	Removed 28	14	12	2 (1 pre op CVA)	0 2 (1 RV sudden, 1 LV, sepsis)
	No attempt 76	40	15	19	1 (S periop hemorrhage) 3
	Unsuccessful attempt 18	9	4	4	
	Total 122	63	31	25	
Intracavitary	Removed 41	37	4	0	0
	No attempt 6	3	0	1 (CVA)	1 B (LV CVA) 1 SH (CRV sepsis)
	Total 47	40	4	1	2
Intrapericardial	Removed 35	7	28	0	0
	Not removed 4	1	0	3 (1 CP, 2 P)	0
	Unsuccessful attempt 1	0	0	0	1 SH (P-Card. Tamponade 11th postop day)
	Total	40	8	28	3

RV, right ventricle; LV, left ventricle; S, septum; CA, coronary artery;

B, bullet; SH, shrapnel; P, pericarditis; CVA, cerebral vascular accident; CP, chest pain.

cirrhosis 8 years after injury and one due to uremia 30 years after injury (Table 11).

Of group 2 patients none died as a result of the cardiac missile. One who underwent removal of the missile developed postoperative pericarditis and one died 19 months after the injury from alcoholic cardiomyopathy.

Discussion

Cardiac missiles may remain in the heart after its direct injury or after an injury to a systemic or pulmonary vein with subsequent embolization into a right or left ventricular chamber, respectively. The retained missile in the heart secondary to direct injury may be partially or completely embedded in the myocardium, it may be free in a cardiac chamber or in the pericardial space, or it may lie next to the pulmonary artery or aorta. The missiles that reach the heart after a venous injury may stay temporarily free in a cardiac chamber and/or become entrapped in the endocardial trabeculations. Missiles free in the left cardiac chamber usually are propelled into a systemic artery during the early period after injury.⁵⁸ Missiles in the right cardiac chambers may either embolize into a pulmonary artery⁵⁹ or venous system or they may be entrapped in endocardial trabeculations and become encysted with fibrous tissue.⁶⁰

The clinical manifestations of a retained missile in the heart immediately after the injury are those produced by the cardiac wound (*i.e.*, cardiac tamponade and/or intrathoracic bleeding). Sometimes, when a valve or the ven-

tricular septum has been injured, symptoms of valvular incompetence, intracardiac shunt, or conduction defects may be present or the patient may be free of symptoms.

Various late clinical manifestations of retained missiles of the heart have been described. Signs and symptoms of systemic or pulmonary embolization of the missile or thrombi, of bacterial endocarditis,^{10,22,61} or of pericarditis^{31,60} and neurotic manifestations of various degrees and character have been reported.^{1,10}

The late clinical manifestations of missiles in the heart are dependent on the site, type, and size of the missiles. Patients with the missiles completely embedded in the myocardium usually are free of symptoms.^{10,18,22,24,29,60} Indeed of 23 patients from groups 1 and 2 with missiles completely in the myocardium none died. Only one patient developed pericarditis and one had a coronary artery to right ventricle fistula. Patients with a missile in the pericardium or pericardial space may develop pericarditis.^{31,60} Of groups 1 and 2, 3 of 4 patients in whom shrapnel was not removed had chest pain or pericarditis and 1 patient who underwent unsuccessful attempt to remove shrapnel developed what seemed to be pericarditis with cardiac tamponade and died on the 11 days after operation. Although the experience is small, the two patients from group 2 (there were none in group 1) with bullets that were not removed from the pericardium, however, had no symptoms or complications.

The missiles that are free in the cardiac cavity or partially protruding into the cavity may produce symptoms of embolization of the missile or thrombi or of bacterial

endocarditis.^{10,22,61} Of group 1 patients with an intracavitary missile, 2 died, both in whom the missile was not removed; 1 patient with a bullet in the left ventricle died from a cerebral vascular accident and 1 with shrapnel in the right ventricle died from sepsis.

Of 86 patients with 94 missiles partially embedded in the myocardium, in whom either no attempt or unsuccessful attempt to remove them was made, 3 patients died. One patient with a missile in the right ventricle died suddenly, perhaps from arrhythmia, and one with a missile in the septum died from sepsis. One patient with a missile in the septum who had an unsuccessful attempt to remove the missile died perioperatively from hemorrhage. In addition 23 patients had symptoms.

Although our patients were not asked any specific questions to uncover neurotic manifestations, nor was any psychological testing done, no group 2 patients in the follow-up period described to any examining physician any specific neurotic symptoms related to the retained missile. Of group 1 patients, 6, all from those in whom the missile was left in the heart, had neurotic manifestations.

In general the results of the management of group 2 patients were better than those of group 1. This may be due to the fact that all missiles in the heart in group 2 patients were smaller with smoother edges, the injury occurred in civilian life, and the period that they were treated was during the most recent 20 years. Whereas in group 1 patients the majority of cardiac missiles were in military personnel during war-time conditions, the missiles in general were of larger size with irregular margins, and the majority of the patients were treated during the early 1950s and 1960s.

The review of the cases reported in the English literature and of our personal experience suggest that the management of cardiac missiles should be individualized. Missiles completely embedded in the myocardium or in the pericardium and pericardial space are tolerated well and they may be left in place. However shrapnel, other than those completely embedded in the myocardium, should be removed. Intracavitary or partially embedded missiles in the myocardium, particularly those in the left side of the heart seen during the early postinjury period, should be removed. However patients with intracavitary missiles on the right side of the heart, except for those in whom the missile has embolized to the heart after first traversing an intestinal viscus, may be observed in anticipation of their embolization in the pulmonary artery, from which they can be removed. Patients with intracavitary or partially embedded missiles in the myocardium seen late may have cardiography initially to determine whether the missiles are completely encapsulated, and if such has occurred the patient may be followed. Symptomatic missiles, especially those manifesting with sepsis, or large missiles, particularly

with irregular margins, and missiles located next to an artery should be removed.

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DISCUSSION

DR. WATTS R. WEBB (New Orleans, Louisiana): We are indebted to Dr. Symbas and his associates for their manuscript and the definitive data on intracardiac and cardiac injuries.

In their 20 years' experience they saw about one case per year. That is about what we see, and it is nice to have this total data accumulated so we can get some actual idea of what goes on, and thereby have some true data on which to base our therapy.

We do much as they do. We ignore pellets unless they are seen at the time we have to operate for other reasons.

Our own experience with shrapnel might be considered that of two cases, one a bit of barbed wire thrown by a lawn mower and the other a coat hanger that extended into the heart. We operated to remove the hanger, although it extended outside and required nothing but very simple extraction, as with a tooth.

The bullets, we agree, should be extracted, particularly if they are intracavitary. We do not wait for them to embolize. If they are on the right side, we go ahead and cardiopulmonary bypass and it is very simple, of course, to retrieve them.

Let me give you one illustration of a bad experience. The woman had a bullet embolized to the left lung. We turned her in the right lateral position to remove the embolus from the left lung, and as we did, the

bullet fell into the right lung. I encourage you, if you turn a patient on his or her side, be sure that you get a cross table lateral before you make an incision on the upside.

The missiles protruding into the myocardium or the chambers seem to be the most difficult, and I would like to ask Dr. Symbas how he handles those.

We use echo extensively. We have not found that injection of contrast gives us any information at all. The CT scan has so much scatter that it is very difficult to know what is going on. What are your indications for operation and timing in this particular group?

Pericarditis resulting from missiles in the pericardium is also a problem. However the pericarditis and development of tamponade can be observed and followed and you can detect it and take care of it very easily, as long as you follow them by frequent echos. This problem is usually over in about 2 weeks.

The cardiac neurosis is interesting and this has been addressed in the literature. We have not seen it, and I think it relates primarily to transmission to the patient of the doctor's neurosis rather than anything intrinsic to the patient.

DR. A. L. PICONE (Closing discussion): In answer to Dr. Webb's questions, the main methodology for evaluating the patients in our series was angiocardiology.

In terms of the timing for operation in these patients, obviously, in