Atrial Level Right to Left Intracardiac Shunt Associated With Postoperative Hypoxemia: Demonstration With Contrast Two-Dimensional Echocardiography

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Transient hypoxemia is not uncommon after major cardiac or thoracic surgery. The differential diagnosis includes atelectasis, pulmonary embolus, pneumonitis, congestive heart failure and several other diverse cardiovascular and pulmonary problems. Less well recognized is transient right to left intracardiac shunting through a patent foramen ovale or previously unsuspected atrial septal defect. Three cases of clinically imp-

Case Reports

Case 1. The patient is a 50 year old white man who underwent three vessel coronary artery bypass surgery for intractable angina after an inferior myocardial infarction. Preoperatively, his physical examination was normal. The chest X-ray film was normal and specifically demonstrated no evidence of an intracardiac shunt or chamber enlargement. A preoperative two-dimensional echocardiogram revealed normal right ventricular size and normal septal motion; there was no evidence of right ventricular volume overload. The inferior wall was akinetic. Preoperative pulmonary function tests revealed a forced vital capacity of 3.31 liters/min and a forced expiratory volume in 1 second of 2.64 liters (80% of predicted maximum). Arterial blood gases while breathing room air demonstrated a partial pressure of oxygen (Po2) of 60 torr, partial pressure of carbon dioxide (Pco2) of 34 torr and pH of 7.45. The operative course was uncomplicated and there was no evidence of perioperative myocardial infarction.

In the immediate postoperative period, arterial blood gas determinations revealed a Po2 of 67 torr and Pco2 of 37 torr during breathing of 100% oxygen with 2.5 cm of positive end-expiratory pressure. The level of positive end-expiratory pressure was gradually increased to 12.5 cm, at which time the Po2 was 35 torr during breathing of 100% oxygen. Hemodynamic measurements obtained at this time revealed a blood pressure of 100/60 mm Hg, heart rate of 130 beats/min, pulmonary capillary wedge pressure of 20 mm Hg, right atrial pressure of 19 mm Hg and a cardiac index of 2.4 liters/min per m². The chest X-ray film revealed no infiltrates, effusion, atelectasis, evidence for congestive failure or volume overload. A right to left intracardiac shunt
was suspected and the positive end-expiratory pressure dis-
continued. The \( P_{O_2} \) increased to 140 torr on 100% oxygen.

A two-dimensional contrast echocardiogram using 10 ml
of agitated saline solution injected peripherally confirmed
the presence of right to left shunting at the atrial level. No
specific therapy directed at the intracardiac shunt was in-
stituted. Before hospital discharge, a radionuclide angio-
graphic shunt study revealed an approximate 15% right to
left shunt. The patient had an uneventful recovery and was
discharged home.

Case 2. The patient is an 81 year old white man who
underwent four vessel coronary artery bypass surgery for
disabling angina after a myocardial infarction. Physical ex-
amination was normal except for an \( S_4 \) gallop. The chest
X-ray film was normal. Echocardiography showed normal
chamber sizes and inferior wall akinesia. Preoperative ar-
terial blood gases, while breathing 2 liters/min of nasal
oxygen, were \( P_{O_2} \) 73 torr, \( P_{CO_2} \) 21 torr, and pH 7.57.

Four vessel coronary artery bypass surgery was per-
formed without complications. Postoperative hemodynamic
measurements consistently showed right atrial pressures to
be 2 to 6 mm Hg higher than pulmonary artery diastolic and
pulmonary capillary wedge pressures (17 to 20 versus 11
to 18). On the sixth postoperative day, despite a normal
physical examination and clear lung fields on chest X-ray
film, the arterial \( P_{O_2} \) was 65 torr (\( f_{O_2} = 0.50 \) by mask).

A two-dimensional contrast echocardiogram revealed a
right to left shunt at the atrial level. A loculated pericardial
effusion causing collapse of the right atrial free wall was
also seen. Using the aveolar shunt equation to determine
QS/QT while breathing 100% oxygen, a 16% shunt was
calculated. Ear oximetry showed that arterial oxygen sa-
turation decreased from 90 to 84% with standing or mild
exercise. Lung volumes, spirometry and diffusing capacity
for carbon monoxide were normal. The patient was dis-
charged on supplemental oxygen.

Case 3. The patient is a 56 year old white man who
underwent coronary bypass surgery for persistent angina
after a nontransmural myocardial infarction. He had no evi-
dence of congestive heart failure and the chest X-ray film
was normal. Preoperative pulmonary function testing re-
vealed a forced vital capacity of 3.18 liters, a forced ex-
piratory volume in 1 second of 2.57 liters (80% of predicted
maximum) and a \( P_{O_2} \) of 77 torr, \( P_{CO_2} \) of 45 torr, pH of
7.43 while breathing 2 liters of oxygen/min. Surgery was
performed without incident and there was no evidence of a
perioperative myocardial infarction.

Postoperatively, the right atrial pressure was 20 mm Hg,
the pulmonary artery pressure was 21/15 mm Hg and the
mean pulmonary capillary wedge pressure was 13 mm Hg.
The patient required an \( f_{O_2} \) of 0.50 or greater to maintain
an atrial \( P_{O_2} \) of 60 torr or greater. The findings on physical
examination of the chest and chest X-ray film were normal.

Two-dimensional contrast echocardiography using 10 ml
of agitated saline solution injected into the right atrium
through an indwelling thermodilution catheter revealed a
right to left shunt at the atrial level (Fig. 1). The remainder
of the patient’s convalescence was unremarkable with grad-
ual reduction in his requirement for supplemental oxygen.

Discussion

Hypoxemia after aortocoronary bypass surgery is usually
due to atelectasis, pulmonary infection, fluid overload,
pneumothorax, or pleural effusion. Less well recognized is
the development (or worsening) of a right to left intracardiac
shunt as a cause of hypoxemia. Our three patients had right
to left intracardiac shunting at the atrial level associated
with hypoxia after otherwise uncomplicated coronary artery
bypass surgery.

Diagnostic role of contrast echocardiography. The
presence of an intracardiac shunt in our patients was first
demonstrated using two-dimensional contrast echocardi-
graphy, which is minimally invasive, easy and safe to
perform (9,10). Contrast echocardiography can detect shunts
as small as 5% and is more sensitive than oximetry or
indicator-dilution methods (11,12). It yields fewer false pos-
tive or false negative results than cardiac catheterization
(12,13) in detecting an atrial level right to left shunt. The
type of contrast medium used (normal saline solution) was
similar to that used by other investigators (6,11,12), as were
the sites of injection. Noninvasive data supporting the pres-
ence of a right to left shunt was obtained in two patients.

Figure 1. Patient 3. Four chamber contrast-enhanced echocardio-
gram. Panel 1 shows the chamber orientation before contrast in-
jection. In panel 2 the contrast (C) medium can be visualized as
it enters the right atrium (RA). Panel 3 shows contrast medium
entering the right ventricle (RV) and crossing the interatrial septum
(IAS) into the left atrium (LA). Panel 4 shows contrast medium
in all four chambers. Arrow illustrates flow across interatrial septum.
Cause of right to left shunt. We hypothesize that the shunt detected in these three patients occurred through a previously occult patent foramen ovale. A patent foramen ovale was found in 27% of subjects at autopsy in a recent large series (8). Lynch et al. (7) demonstrated right to left shunting through a patent foramen ovale in 18% of normal subjects using contrast echocardiography combined with the Valsalva maneuver. Conditions that favor an occult shunt becoming manifest include those that increase right atrial pressure to equal or exceed left atrial pressure. All three patients met this criterion. Additionally, Patient 2 was found to have an isolated abnormality of right atrial filling on echocardiography. Therefore, it is not unreasonable to assume that a reduction in right atrial, right ventricular or pulmonary artery compliance caused an occult patent foramen ovale to become manifest as a mechanism for atrial level right to left shunting.

Cause of right ventricular dysfunction. The exact cause of the reduced right ventricular compliance cannot be determined in these cases. Right ventricular infarction, positive end-expiratory pressure and cardiac tamponade, with either a globally distributed or a loculated effusion, may produce decreased compliance of the right-sided cardiac structures. All of our patients had evidence for shunting after mechanical ventilation had been discontinued. There was no evidence of diastolic collapse of cardiac chambers except as described above. All of our patients had disease of the right coronary artery and two had evidence of previous inferior wall infarction. Occult right ventricular infarction cannot be excluded and may have been a likely mechanism for the observed shunt in Patients 1 and 3. A small, clinically silent pulmonary embolus may also have been present and was not excluded by nuclear scanning or pulmonary angiography. A final consideration is transient right ventricular dysfunction following incomplete cardioplegia of the right ventricle at the time of surgery (14,15).

Conclusions. We have presented three patients with right to left intracardiac shunting at the atrial level documented by contrast echocardiography after otherwise uncomplicated coronary artery bypass surgery. In no case did the clinical or echocardiographic preoperative assessment suggest the presence of an atrial septal defect. Although each of our patients demonstrated preoperative hypoxemia, in each it was presumed to be secondary to pulmonary disease and not intracardiac shunting. We hypothesize that this phenomenon represents right to left intracardiac shunting through a previously clinically silent patent foramen ovale that postoperatively allowed substantial shunting and production of clinically important hypoxemia. The incidence of this phenomenon is unknown but our detection of three such cases in a 6 month period suggests that it may not be uncommon. Further studies are needed to define the incidence and overall magnitude of this problem.

References