Krypton-85 in the Detection of Intracardiac Left-to-Right Shunts

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A NUMBER of methods have been developed for detecting left-to-right shunts during cardiac catheterization of which the most frequently employed is determining the difference in oxygen saturations. This method has limited application in the presence of small shunts, however, since the minimal changes are often within the error of this method. Therefore, other more sensitive techniques have been employed including the use of radioactive gases, dye dilutions, hydrogen ion-platinum electrode systems, and cineangiography.

Braunwald's group initially employed nitrous oxide for the detection of intracardiac shunts and then developed a method for the detection of left-to-right shunts using krypton-85. It was found that this gas could be the basis for a sensitive screening test and could also localize such shunts. It is the purpose of the present study to report the results in 175 patients in whom krypton-85 was employed for the detection of intracardiac shunts.

Method

The method reported by Braunwald et al. was utilized in the present study. The patient hyperventilated a krypton-85 and air mixture provided in a concentration of 0.4 μc./L. of air. Before the mixture was inhaled, the catheter tip was placed within a preselected right-sided chamber and samples of blood were drawn through both the catheter and an indwelling peripheral arterial needle to determine the background of radioactivity. While the gas mixture is inspired, 5- to 8-ml. blood samples were withdrawn simultaneously from the catheter and arterial needle between the tenth and thirtieth seconds of krypton-85 inhalation. The degree of radioactivity in the two samples was determined in a Geiger-Muller tube through a decade scaler. After the background activity was subtracted, the radioactivity of the catheter sample was expressed as a percentage of the systemic arterial blood count.

In each instance, oxygen saturations were determined on a double-scale Water's colorimeter or Van Slyke apparatus and in a number of patients, confirmation was obtained by dye-dilution techniques or cineangiography. A shunt was considered present by oxygen saturations with a step up of 2 vol. per cent at the atrial level, 1 vol. per cent at the ventricular level, and ½ vol. per cent in the pulmonary artery. Only those patients are included whose diagnoses were established by clinical, x-ray, electrocardiographic, and vectorcardiographic data. Final correlations to surgical or necropsy findings were made when available.

Results

In 117 patients not found to have a shunt by clinical findings and oxygen saturations, the pulmonary artery samples after krypton-85 inhalation averaged 5.9 per cent of the arterial activity. Eleven patients exceeded 12 per cent, and five patients had values of 15

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Krypton-85 inhalation in atrial septal defect.

to 20 per cent (fig. 1). In 29 patients with atrial septal defects, the right atrial specimens distal to the shunt ranged from 14.2 to 100 per cent. Five patients had values less than 20 per cent. The vena cava values proximal to the shunt averaged 8.4 per cent (fig. 2). Three patients with partial anomalous venous drainage had vena caval samples of 34, 21.5, and 23 per cent. In 19 patients with ventricular septal defect, the right ventricular samples averaged 36.2 per cent. Six patients had values of 15 to 20 per cent. Proximal to the shunts, the right atrial specimens ranged from 0 to 12.8 per cent (fig. 3). In 10 patients with patent ductus arteriosus, the pulmonary artery specimens averaged 38.1 per cent. There were no values less than 21 per cent. Proximal to the shunts, the right ventricular values averaged 8 per cent with only one patient exceeding 15 per cent (fig. 4).

In the 58 patients with positive krypton-85 tests, there was evidence of a left-to-right shunt by oxygen saturations in 52. In the 117 instances of a negative krypton-85 test, oxygen saturations suggested a left-to-right shunt in two patients (table 1).

Discussion

Braunwald et al. have reported “... there was no overlap in the results in the two groups of patients” with use of krypton-85 for the detection of left-to-right shunts. In patients

<table>
<thead>
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<th>Table 1</th>
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<tr>
<td><strong>Results of Krypton-85 Test</strong></td>
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<tr>
<td><strong>Positive for shunt</strong></td>
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<tr>
<td>58 patients</td>
</tr>
<tr>
<td>O₂ positive for shunt</td>
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<td>52 (90%)</td>
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without shunts, the radioactivity at the intracardiac site as expressed as a percentage of the systemic arterial blood count was 0 to 12 per cent. In patients with shunt, the range was 13 to 113 per cent.\(^7\)

In the present study, the krypton-85 test appeared to be of particular value in the detection of shunts too small for detection by determining oxygen saturation; six such patients showed shunts by the krypton-85 technic. There appeared to be a rough correlation between the degree of krypton-85 elevation and the size of the shunt, but no quantitation could be made from our data. Results less than 15 per cent were considered negative and more than 20 per cent, positive. Because of some overlapping of results in the 15- to 20-per cent range, determinations falling within these limits are probably best considered as nondiagnostic.

Four of 58 patients with shunts showed krypton-85 values distal to the shunt below 15 per cent although at the shunt site values above 15 per cent were obtained. Thus, the use of multiple sampling sites is of additional value in contrast to sampling restricted to the pulmonary artery as a screening method. Certain limitations were encountered with respect to the detection of the site of shunting. In atrial defects, mixing of shunted blood may or may not extend to the superior vena cava or high right atrial position. This in combination with the occasional presence of associated partial anomalous venous drainage as in three of our patients may result in elevation of the vena caval krypton-85 sample. In one instance a patient with a demonstrated atrial septal defect had negative krypton-85 values with the catheter tip in the high right atrial position.

The association of valvular insufficiency may falsely localize the shunting site with use of krypton-85, oxygen saturation, or a hydrogen ion-platinum electrode system. One patient shown at operation to have a patent ductus arteriosus and pulmonic and tricuspid insufficiency, had elevated krypton-85 values in the right atrium and ventricle as well as in the pulmonary artery. Another patient with patent ductus and probable pulmonic insufficiency had positive values in the ventricular sample. Low arterial counts may result from insufficient inhalation of the gas because of the failure of the patient to hyperventilate properly. Two patients were excluded for this reason. One patient with rheumatic heart disease and mitral insufficiency, but no detectable septal defect or patent ductus as determined at time of open heart surgery, had krypton-85 values of 28, 21, and 21 per cent in the right atrium, ventricle, and pulmonary artery, respectively. Oxygen saturations and cineangiocardiology did not reveal a shunt. These conflicting results remain unexplained.

Hyman et al.\(^8\) noted that the oxygen method failed to detect or localize shunts well demonstrated by dilution technics in 18 per cent of patients with left-to-right shunts; there are no data available on the sensitivity of the krypton-85 technic as compared to dye-dilution methods. One disadvantage in children is that the krypton-85 method requires significantly large blood samples as compared to technics by a hydrogen ion-platinum electrode system. Braunwald stated "Krypton-85 may be employed with confidence for deter-

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**Figure 4**

*Krypton-85 inhalation in patent ductus arteriosus.*

![Graph](image-url)
mining the presence of a left-to-right shunt."7
The exclusion from his report of results not
confirmed by surgery may be responsible for
the lack of any overlap in his data. In the
present report, minimal lesions are included
in patients who did not require surgery and
who had well-confirmed lesions on the basis
of clinical and laboratory data. It is in patients
with small shunts that more sensitive indica-
tors are required.
Although quantification of left-to-right shunts
with this technic was not done in the pres-
ent study, it has been pointed out by others
that it is possible to estimate the ratio of
pulmonary to systemic flow utilizing inert
gases such as krypton-85 and nitrous oxide.7, 9
This then represents a distinct advantage in
this method for evaluating shunts as compared
with the hydrogen gas method.

Conclusion and Summary
In 175 patients studied by the krypton-85
inhalation test, 58 patients demonstrated a
left-to-right shunt. In six of the cases a shunt
was not detected by differences in oxygen
saturation. Some overlapping of results was
observed and limitations of the method in-
cluded the requirement for significant blood
sampling, irregular chamber mixing, and
associated defects. The krypton-85 test is
considered to be a useful ancillary method
for the detection of shunts. Its sensitivity per-
mits the detection of small intracardiac shunts
not demonstrated by oxygen saturation.

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Lectures and Learning
The proper function of lectures is not to give a student all the information he needs,
but to rouse his enthusiasm so that he will gather knowledge himself, perhaps under
difficulties.—J. J. Thomson.
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