PREPARATION AND ASSEMBLY OF THE STAINLESS STEEL SPONGE DEBUBBLER FOR USE IN THE HELIX RESERVOIR BUBBLE OXYGENATOR

BY

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Pumps to replace the function of the heart temporarily are readily available, but oxygenators that will physiologically perform the function of respiration are still in the process of development. Bubble, membrane, and film oxygenators are now being used in various centres, and some workers attempt to improve the efficiency of their apparatus by adding more and more safety devices and control gadgets.

In medicine few methods are ever ultimate, but the essential of reliability is simplicity, and we feel that, when used without unnecessary gadgets, the bubble oxygenator is safe and efficient. This is not merely an impression. Clinical application to over 70 patients using the high-flow principle during the past one and a half years at the Groote Schuur Hospital and the Red Cross War Memorial Children’s Hospital has resulted in only eight deaths. The oxygenator is effective, non-traumatic to blood, easy to assemble and work, and free from mechanical failure. We have lost no patients as a result of failure of the heart-lung machine, and in the last 31 patients operated upon for congenital heart defects there have been no deaths.

Since our detailed description of the assembly and use of the helix-reservoir bubble oxygenator (McKenzie and Barnard, 1958), on the advice of Dr. R. L. Varco, of the University of Minnesota Hospitals (Varco and Hodges, 1959), we have changed to the stainless steel sponge debubbling system. This change simplifies the assembly of the heart-lung machine and has increased its safety and efficiency. It is the purpose of this paper to describe the preparation and assembly of this new debubbling chamber.

Debubbling is effected by four anti-foamed stainless steel sponges arranged around the perforated top of the mixing tube, and seated in a “teflon”-coated can (Fig. 1).

MATERIALS

The can.*—This is a stainless steel cannister, 7 in. deep and 5½ in. in diameter. The inside of the can is coated with “teflon.” A hole measuring 1¼ in. in diameter is made in the centre of the bottom of this can, and this will just allow the mixing tube (made of “tygon” or “mayon,” with an internal diameter of 1½ in. and a wall thickness of ¼ in.), to pass through, giving a blood-tight fit. Another hole, 1½ in. in diameter, which will allow the escape of gases, is made in the centre of the can’s lid. Two peripherally placed outlets, large enough to take a “mayon” tube ½ in. internal diameter, are fitted and secured in the bottom of the can (Fig. 3).

Mixing tube.—The mixing tube (made of “tygon” or “mayon”) is 2 ft. 8 in. long, has an internal diameter of 1½ in. and a wall thickness of ¼ in. Its top is perforated with about 30 holes, each ½ in. in diameter. The area in which the holes are situated extends from about 1 in. to about 4½ in. from the top of the tube (Fig. 4). These holes are pressed in the tube by means of a specially turned and sharpened piece of pipe (diameter ½ in.) used in conjunction with a vice.

Four stainless steel sponges* are used with each mixing tube. These sponges are first boiled in a 5% solution of sodium hydroxide for half an hour. They are rinsed thoroughly and a sample of the last rinsing water is tested with B.D.H. universal indicator to ensure that there is no alkali left. The sponges are then washed with a solution of powdered detergent (such as “surf”) and again rinsed thoroughly and then dried in a hot air oven set at 400° C.

Antifoam.—This is prepared by mixing 75 g. of anti-foam XC-2-0033† with 100 ml. of anaesthetic ether to form a thick paste. A further 100 ml. of ether is mixed in and the mixture is allowed to stand overnight. The next day 800 ml. of ether is added in 100 ml. amounts and the mixture is stirred well between each addition of ether.

* Obtainable from the Phelan Manufacturing Co., 2523 Minnehaha Ave., Minneapolis, Minnesota, U.S.A.
† Manufactured by Lever Bros. (SA) Pty. Ltd., Durban.
**FIG. 1.**—Diagrammatic cross-section of stainless steel sponge debubbler for use in the De Wall/Lillehei helix-reservoir bubble oxygenator, showing the arrangement of the various components.

**TWO 3/8 CONNECTORS.**

- 3/4 DEPTH OF LID.
- STAINLESS STEEL STOPPER.
- SPONGE NO. 2.
- SPONGE NO. 3.
- SPONGE NO. 4.
- SPONGE NO. 1.
- 3/8 HOLE.
- 1 1/2 HOLE IN CAN.
- 1 1/2 (I.D) MAYON TUBE.

**FIG. 2.**—The various unassembled parts of the debubbler system.

**FIG. 3.**—The mixing tube is shown after insertion into the bottom of the can. The two peripherally placed outlets can also be seen.

**FIG. 4.**—The top of the mayon mixing tube, showing the placing of holes which are made with the specially turned pipe which can also be seen in this photograph.

**FIG. 5.**—The stainless steel sponges have all been placed over the holes at the top of the mixing tube to form the closely knit barrier through which the oxygenated blood must pass.

**FIG. 6.**—The lidless cannister, as seen from the top. The stopper can be seen in place at the end of the mixing tube, around which the sponges are arranged.
The antifoam mixture is now transferred to four large centrifuge bottles and then centrifuged in an M.S.E. refrigerated centrifuge at 1,500 r.p.m. for 30 minutes. The supernatant fluid, which is pure antifoam in ether solution, is slightly opalescent, but not cloudy. (Separation of the particulate matter, particularly silica, can also be achieved by allowing the solution to stand for two days.) This fluid is decanted into dark bottles and the residue is discarded. One thousand millilitres of antifoam is sufficient for dipping about 20 sponges.

**ASSEMBLY**

The mixing tube is washed, rinsed, and dried. The sponges are dipped in the antifoam/ether solution and allowed to drip dry. They should be spotlessly clean and when dipped into the antifoam/ether solution they should

### Table I

PERFUSION DATA OF FIRST 33 OPEN HEART OPERATIONS PERFORMED USING STAINLESS STEEL SPONGE DEBUBBLING SYSTEM IN CONJUNCTION WITH HELIX-RESERVOIR OXYGENATOR

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Lesion</th>
<th>Weight (kg.)</th>
<th>Perfusion Duration (min.)</th>
<th>Highest Flow Rates (ml/min)</th>
<th>Arterial Pressure during Perfusion (mm. Hg.)</th>
<th>Haemolysis (mg/%)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Pulmonary valvar stenosis</td>
<td>35</td>
<td>14</td>
<td>2,450</td>
<td>70</td>
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<td>Satisfactory</td>
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<td>40</td>
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<td>3,000</td>
<td>75</td>
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<td></td>
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<tr>
<td>21</td>
<td>Tetralogy of Fallot</td>
<td>57</td>
<td>99</td>
<td>3,135</td>
<td>55</td>
<td></td>
<td>101</td>
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<tr>
<td>23</td>
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<td>48</td>
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<td>3,120</td>
<td>65</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>25</td>
<td>Pulmonary infundibular stenosis + tricuspid incompetence</td>
<td>32</td>
<td>69</td>
<td>3,200</td>
<td>100</td>
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<td>65</td>
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<td>84</td>
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<td>65</td>
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<td>51</td>
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<td>120</td>
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<td>75</td>
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<tr>
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<td>71</td>
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<td>75</td>
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<td>61</td>
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<td>47</td>
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<td>34</td>
<td>1,600</td>
<td>80</td>
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<td>80</td>
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<td>75</td>
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<td>85</td>
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<td>85</td>
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<td>73</td>
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<td>84</td>
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<td>50</td>
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<td>55</td>
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<td>85</td>
<td>4,020</td>
<td>60</td>
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<td>95</td>
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<td>45</td>
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<td>92</td>
<td>1,600</td>
<td>113</td>
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<td>40</td>
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<td>91</td>
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<td>26</td>
<td>2,080</td>
<td>80</td>
<td></td>
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<td>98</td>
<td></td>
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<td>80</td>
<td>3,520</td>
<td>68</td>
<td></td>
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</tr>
<tr>
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<td>94</td>
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<td>69</td>
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<td>3,350</td>
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<td>80</td>
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<tr>
<td>70</td>
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<td>2,550</td>
<td>85</td>
<td></td>
<td>60</td>
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<tr>
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<td>16</td>
<td>92</td>
<td>1,440</td>
<td>90</td>
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<td>60</td>
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Died: Satisfactory

Result:

- Satisfactory
- Died
- 3
- 4
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- 70
- 71
**STAINLESS STEEL SPONGE DEBUBBLER**

**TABLE II**

*pH AND CO₂ DETERMINATIONS FROM SAME BLOOD SAMPLE FROM INTERNAL MAMMARY ARTERY IN EACH CASE*

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Defect</th>
<th>Duration of Perfusion (min.)</th>
<th>pH</th>
<th>Total CO₂ (m Eq. l.)</th>
<th>Total Oxygenation (%) During Bypass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>During</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>59</td>
<td>Ventricular septal defect</td>
<td>68</td>
<td>7.35</td>
<td>7.44</td>
<td>—</td>
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<tr>
<td>31</td>
<td>Pulmonary valvarus stenosis</td>
<td>23</td>
<td>7.36</td>
<td>7.32</td>
<td>—</td>
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<tr>
<td>29</td>
<td>Atrial septal defect</td>
<td>28</td>
<td>7.36</td>
<td>7.42</td>
<td>7.32</td>
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<tr>
<td>54</td>
<td>Endocardial cushion defect</td>
<td>37</td>
<td>7.39</td>
<td>7.41</td>
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<tr>
<td>40</td>
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<td>120</td>
<td>7.41</td>
<td>7.33</td>
<td>7.36</td>
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<tr>
<td>43</td>
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<td>111</td>
<td>7.42</td>
<td>7.41</td>
<td>7.36</td>
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<tr>
<td>47</td>
<td>Pulmonary valvarus stenosis</td>
<td>34</td>
<td>7.43</td>
<td>7.39</td>
<td>—</td>
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<td>26</td>
<td>7.43</td>
<td>7.39</td>
<td>7.44</td>
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</tbody>
</table>

Samples were taken just before bypass, during bypass at 20 minutes, and 10 minutes after bypass. Blood for oxygen estimation was taken from the arterial and venous lines immediately after bypass.

not discolor it. The sponges are then arranged over the holes as follows (Fig. 1): two are arranged one above the other, well above and below the level of the holes, overlapping slightly at their junction. The third and fourth sponges are then pulled right over the first two, to form a closely knit barrier through which the oxygenated blood passes (Fig. 5). This unit is then wrapped in a cloth and autoclaved. The can is wrapped and autoclaved separately.

On the morning of surgery the debubbling system is assembled under sterile conditions. The bottom end of the mixing tube is inserted through the centre hole in the can and the tube is then pulled down until the sponges are seated in the can. Care must be taken not to move the position of the sponges and to see that all the holes in the tube are well covered. The upper end of the mixing tube is closed with a stainless steel or rubber-covered nylon stopper (Fig. 6).

The oxygen dispersal plate is placed in position at the lower end of the mixing tube. The lid is placed over the top of the can and strapped down. A piece of ½ in. "mayon" tubing is placed over one of the connectors in the can, and this 16-in. long tube delivers blood into the helix. An adjustable clamp is placed on this tube to regulate the flow of blood. A shorter piece of ½ in. tubing is placed over the other connector, bent to 180°, and strapped to the side of the can to act as a depth gauge. To avoid aspirating air, a reservoir of about 100 ml. blood is kept in the can and this level is marked on the gauge.

**RESULTS**

This type of debubbling system has been used in our last 53 open heart cases, and Table I gives some perfusion data. Flow rates were calculated in ml. per kilogram body weight per minute, varying according to the weight of the patient, a higher flow per kg. per minute being used in the smaller patient. The minimum flow rate in this series was 50 ml./kg./min. and the maximum 113 ml./kg./min. The time of perfusion varied between 14 minutes and 146 minutes, the average length of time being 80 minutes.

Venous drainage varied between 25 cm. being established between the height of the operating table and the venous well. The venous pressures measured between 7 mm. Hg and 20 mm. Hg with a mean of 14 mm. Hg.

On an average, haemolysis was about 1 mg. % haemoglobin per minute of perfusion, except in patients Nos. 37 to 43 during which period faulty pump hoses with rough inside surfaces were used. Since these were discovered and replaced, no abnormal haemolysis has been encountered. In all patients there was minimal post-operative bleeding, indicating very little disturbance in the blood clotting mechanism. These facts show that destruction of blood was minimal.

The return of oxygenated blood was always into the right femoral artery and the perfusion pressure varied from 40 mm. Hg to 120 mm. Hg with a mean of 80 mm. Hg. Oxygenation and removal of carbon dioxide was always adequate (Table II).

All patients who survived the operation regained consciousness immediately anaesthesia was discontinued, and the electroencephalographic follow-ups indicated no major variation from pre-operative studies.

**CONCLUSION**

Though there are several types of oxygenators, we have found the bubble oxygenator, used with a modicum of extra gadgets, to be reliable and efficient. We have used this system in 53 open heart operations and the results bear out the reliability and safety of this equipment. From these results we may conclude that the bubble oxygenator, when used with the necessary precautions, is efficient and safe,
and, using the new debubbling system, there is no
danger of antifoam or air embolism, even when high
flows of up to 4 litres per minute are used.

We wish to thank Professor J. H. Louw, of the
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Herman, and Fourcade bequests, and also to the Council
for Scientific and Industrial Research, for financial
assistance.

REFERENCES
Preparation and Assembly of the Stainless Steel Sponge Debubbler for Use in the Helix Reservoir Bubble Oxygenator

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