Aerosols in the mortuary

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SUMMARY Air counts in seven mortuaries during necropsies revealed that providing care is taken with washing intestines and close dissection, bacterial numbers are often less than those found in an operating theatre, and relate more to the number of people and movement in the room than the work. The acknowledged hazard of work in the mortuary seems to depend more on contact with infected material, and particularly with splashes on surfaces, than to inhalation of infectious material. Mortuaries should be ventilated, if only to contain the smell, but the recommendations of the *Howie code of practice* seem more than adequate. Provision of exhaust hoods for close dissection should be considered. Mortuary surfaces should be crack-free and easy to clean, and the room free of needless equipment.

Several reports in the 1930s exposed the hazards of the mortuary for both pathologist and medical student with respect to tuberculosis. Morris¹ studied tuberculosis in 449 medical students between 1932 and 1944. Tuberculin tests were positive in 58% of the 1932 students, and 26% of 1944 students; all the former intake and 94% of the latter intake had converted by the end of their second preclinical year, part of which was spent in the laboratory and the mortuary where the students washed their hands in the sink used for specimens. Two girls who helped mount museum specimens were among 56 clinical cases. Hedvall² reported similar findings in Sweden, where 11% of students developed tuberculosis, again related to the preclinical pathology course. He recovered mycobacteria from towels, trays and necropsy tables. Meade³ also incriminated the mortuary, and quoted an observation that mycobacteria were projected eight inches (20 cm) into the air when a tuberculous lung was sliced.⁴ Today mortality from tuberculosis is approximately 1000 deaths/yr and the risks have diminished greatly. Nevertheless a retrospective survey of 21000 medical laboratory workers in England and Wales by Harrington and Shannon⁵ revealed 18 cases—five times the incidence in the general population; 33% were mortuary staff, thus re-emphasising the hazards of the mortuary. However Harrington and Shannon⁶ found no excess in deaths from tuberculosis among mortuary workers. Their retrospective survey noted that the mortuary was a source of hepatitis (type unknown) for those working there, but regular

surveys by Grist⁷ show that this is a minor problem now that the dangers of HB antigen containing blood are understood.

Published data thus suggest that working in the mortuary presents a hazard; and this was recognised in the *Howie code of practice for the prevention of infection in post mortem rooms*. The *Code of practice* notes that direct contact and aerosols may be risk factors and advises how to deal with both. The literature implies that contact is more of a hazard than aerosols. The medical students washed in a contaminated sink; hepatitis is not an airborne infection, and Hedvall² demonstrated extensive surface contamination.

Pathologists vary in dissection of organs, some use a table over the body, while others remove the organs to a side table. Washing of some organs—notably intestines—is usually done in a sink. The use of power saws, either small electric saws for the head, or band saws for long bones presents an obvious aerosol hazard.

This paper reports studies on bacterial aerosols generated during post mortems, studied in several different mortuaries with ventilation systems ranging from nil to excellent.

Material and methods

MORTUARIES VISITED

Tests were done in seven mortuaries: Papworth (before and after upgrading), Cambridge, Huntingdon, Hammersmith, King's Lynn, and Birmingham (Coroner's mortuary).

Papworth (before upgrading)

The room at Papworth had one table with a cross flow extract system based on extractor fans in the windows opposite the pathologist. No air was supplied, so that air changes were less than five times per hour.

Papworth (after upgrading)

The room was retested after being equipped with two tables and a new cross flow system, which included a supply of clean air and an exhaust producing 15 air changes per hour.

The pathologist and his assistant worked very quietly (except for the arrival of students-qv); the organs were dissected over the body, intestines were washed in a sink at the foot of the table, and an electric saw was used to remove the skull.

Cambridge

This mortuary had a good ventilation system with floor extract and a large exhaust duct leading to the incinerator chimney. It contained two tables, which were used simultaneously. Thus there was considerable movement from the staff and students. The organs were dissected over the body, the intestines washed in a side sink, and a manual saw was used to remove the skull.

Huntingdon

The mortuary was a large, old room, with one table and no ventilation. It was only used occasionally. The pathologist and one helper worked quietly, using Papworth techniques.

Hammersmith

The mortuary had four tables; as it had no ventilation it had been criticised by the Health and Safety Inspector. Two necropsies were usually performed simultaneously; they took up to 2.5 h, and occupied up to seven staff; on one occasion during the tests 10 people were present. Organs were dissected at a side table, and intestines washed in a separate sink.

King's Lynn

The mortuary was the new "best buy" hospital design fitted with Pland draught mortuary tables. The pathologist worked quietly with an assistant; the organs were dissected at side tables, and an electric saw was used. Tests were repeated with the table ventilation switched on and off.

Birmingham

The Coroner's mortuary had three tables and was regularly used for up to 13 necropsies per day. Four bodies were examined consecutively by one

pathologist during a session. The test session lasted 90 min. As the pathologist moved from one patient to the next, the attendants sewed up and removed the bodies so that by completion of the fourth necropsy the mortuary was otherwise empty. During the tests three mortuary attendants, the pathologist and two testers were present. There was considerable movement. The room was provided with an input and extract ventilation system with powerful fans, which was not much used as it appeared to be unbalanced and tended to make the adjacent offices unpleasant; furthermore the incoming air was at external temperature.

BACTERIOLOGY

Bacterial aerosols were measured using a Casella slit sampler set to collect 175 litres of air per minute. The sampler was placed beside the necropsy table opposite the pathologist, at the level of the body. Ten to twelve 2-min (350 l) samples were taken at intervals of not less than five minutes before and during the necropsy, with the sampler being moved to sinks, side tables etc where relevant.

Two smaller (28 l/min) samplers were used at the Hammersmith Hospital. They were sited 1 m apart opposite the pathologist and run for 5 instead of 2 min. Counts were then added and expressed as particles per 350 l, to compare with the other results.

Particle size analysis was estimated with the Andersen Sieve Sampler, sampling at 28 l per min for 20 to 40 min, while simultaneous counts were done with the Casella sampler.

The Biotest centrifugal sampler was used to detect aerosols in the mortuary exhaust ducts and the counts were correlated with those obtained simultaneously in the room. The Biotest sampled 40 l/min, and was run for 8 min. Samples were taken onto blood agar plates (nutrient agar for the Biotest sampler) which were incubated at 37°C for 18 h. The total number of colonies, the numbers of *Staphylococcus aureus*, of coliforms and *Pseudomonas* were counted. The coliforms and *Pseudomonas* were presumed to be a marker of organisms released from corpses.

Results**AEROSOLS**

Tests were run during five necropsies in each of the two Papworth mortuaries, and in Cambridge. Tests 4 and 10 at Papworth were done during necropsies on patients who had died with septicaemia. Three tests were run with the ventilation to the Kings Lynn tables on, and three with the ventilation off. Three tests were run without ventilation at Birmingham, followed by one with ventilation. Two tests were run

at Hammersmith, and one at Huntingdon. Altogether 28 necropsies were tested. The mean counts of bacteria containing particles/350 l air were:

<i>Papworth (before upgrading)</i>	37
<i>Papworth (after upgrading)</i>	20
<i>Cambridge</i>	24
<i>Huntingdon</i>	35
<i>Hammersmith</i>	210
<i>King's Lynn (ventilation on)</i>	22.8
<i>King's Lynn (ventilation off)</i>	23.7
<i>Birmingham (ventilation on)</i>	139
<i>Birmingham (ventilation off)</i>	260

Tables 1-5 show the air counts per 350 l in the first five test mortuaries. The mean counts exclude controls performed after the bodies were laid out, but

before the necropsies commenced. The figures in parentheses are the number of coliforms in the air. The other organisms were mainly Gram-positive cocci, notably *Staph epidermidis*, and sarcina; *Staph aureus* colonies were too few to justify recording. An exception (q.v.) was in the second test at Hammersmith, when the predominant organisms were aerobic spore-bearing bacilli.

Counts during the necropsy at Huntingdon averaged 35/350 l, compared with a control count of 54; only six coliforms were found in the whole 3 500 l of air tested.

The Hammersmith necropsies lasted a long time so more samples were taken. The first test produced an average count of 70 (16 samples), and the sec-

Table 1 *Papworth (before upgrading)*

Sample No	No of viable particles per 350 l air in five test necropsies				
	1	2	3	4	5
Pre necropsy	56	63(3)	45	60(3)	—
1	32	40(1)	23	45(2)	20(1)
2	25(1)	28	22	57(20)	27
3	25(4)	18	10	60(50)	37(2)
4	25(2)	31	24(1)	48(31)	33(1)
5	35(1)	37(1)	40(4)	48(17)	55(1)
6	27	29	26(3)	54(20)	11
7	20(2)	28(2)*	58(39)*	30(5)	14
8	16(2)*	18	27	90(50)	31(9)*
9	20	41	22	75(40)	59(8)
10	26	—	15	200(186)*	33(1)
11	18	—	22(1)	45(9)	53(2)
12	30(2)	—	—	—	70(4)
Mean counts	25	30	26	68	37
Seven students enter	100	—	—	—	—

() = No of coliforms.

*Washing intestines.

No 4 had infarcted bowel and generalised septicaemia.

Table 2 *Papworth (after upgrading)*

Sample No	No of viable particles per 350 l air in five test necropsies				
	6	7	8	9	10
Pre necropsy	40	11	—	30	28
1	35	22	17	15	21
2	20	14(1)	18	16	30
3	22	17	10	19	33(1)
4	41	15	13	7	35(1)
5	24	3	6	18	36(1)
6	27	10	17	24	13(1)
7	5(5)*	12	7	18	9(1)
8	12	18(4)	24	20	28(5)
9	25	8(1)	46(12)*	39	25(25)*
10	—	14(1)	11	24	36
11	—	—	12	18	—
12	—	—	21(1)	—	—
13	—	—	22	—	—
Mean counts	23	13	17	20	27
Entry of students	33	6	—	—	—

() = No of coliforms.

*Washing intestines.

No 10 had *Pseudomonas pneumonia* and terminal septicaemia.

Table 3 Cambridge

Sample No	No of viable particles per 350 l air in five test necropsies				
	11	12	13	14	15
1	30	22(1)	17(1)	17	21(2)
2	45	5	8	18	48(5)
3	37	8	12	15	25
4	13	12(1)	10	10	257†
5	20(2)	22(1)	10	18	22
6	30(3)	53(15)	11	50(13)§	16
7	40(2)	43(5)	16(2)	0	15
8	29(1)	15	20(8)	14	32(3)
9	50(8)	—	18(2)	10	16(2)
10	28(1)*	80(60)*	7	14	29
11	28	12(2)	5	16	86(26)*
Mean counts	32	27	12	16	31†

() = No of coliforms.

*Washing intestines.

†Excludes the 257 count.

‡Sampler beside pathologist (bacteria = *Staph albus*).

§Squeezed lungs and oesophagus.

*Necropsy 15' comprised two post mortems done on adjacent tables.

Table 4 King's Lynn

Sample No	No of viable particles per 350 l air in six test necropsies					
	16	17	18	19	20	21
1	62	5	11	28	14	38
2	22(1)	8	5	18(1)	22	28
3	44	16	18	59	9	10
4	37	8	16	55(2)	25	20
5	35(2)	8(1)	14	39	12	15
6	—	15(1)	12	35	19	14
7	—	17	24	45	30(9)	14
8	—	—	—	22	—	19
9	—	—	—	—	—	10
10	—	—	—	—	—	4

() = No of coliforms.

Necropsies 16,17,18 = table ventilation on: mean = 23/350 l air.

Necropsies 19,20,21 = table ventilation off: mean = 24/350 l air.

Table 5 Birmingham

Sample No	No of viable particles per 350 l air in four test necropsies			
	22	23	24	25
1	270(7)	258(78)	242(44)	146(6)
2	333(8)	259(45)	272(76)	137(7)
3	266(19)	219(57)*	218(28)*	146(30)*
4	219(12)	373(109)*	197(42)	127(10)*
5	—	268(60)*	—	—
Mean	272(12)	275(70)	231(47)	139(13)
Before testing	— 365(13), after testing — 60(+ fungus)			

() = No of coliforms.

*At sink.

Necropsy 25 — ventilation on.

Table 6 Particle size analysis

Test	Volume (l)	Particle counts		
		>7µm	4.7–7µm	<4.7µm
Papworth	1200	24(20)	8(4)	24(8)
Bham	600	89(9)	104(19)	179(54)
Bham	600	40(2)	48(2)	104(15)

AEROSOL PARTICLE SIZE ANALYSIS

Three particle size analyses were performed: at Papworth (for 40 min during test 10), and at Birmingham (for 20 min during tests 23–24 with the ventilation off, and during 25 with it on). The results are shown in Table 6. Many coliform-containing particles were >4 µm in diameter and so unable to enter the lungs.

A blood agar plate was exposed on the air sampler trolley for 3 h during the same test (No 10) at Papworth and revealed 40 particles, 25 of which con-

ond (24 samples) of 300 particles per 350 l. Only 38 coliform-containing particles were found in the first necropsy, and three in the second (in 6900 and 7500 l of air respectively). On both occasions the coliforms appeared during washing intestines.

Table 7 *Viable particles in mortuary and exhaust duct air (counts per 350 l air)*

Sample No	1		2		3		4	
	Mort	Duct	Mort	Duct	Mort	Duct	Mort	Duct
1	33	17	22	13	19	13	17	14
2	96	150	5	25	17	7	15	7
3	30	20	12	12	7	5	50	25
4	37	20	15	12	—	—	—	—
5	—	—	12	10	—	—	—	—

Mort = mortuary (slit sampler).

Duct = exhaust duct (centrifugal sampler).

tained coliforms; three of the latter were in fact splashes composed of at least 20 colonies.

EXHAUST AIR

Table 7 shows the number of viable particles in the Cambridge mortuary exhaust duct, and those found in the mortuary at the same time. Although the tests were done with different samplers, the results were similar. Counts from the hospital front hall for comparison were 150–300 particles per 350 l (repeated five times with both samplers).

Discussion

The number of bacteria-containing particles in the mortuary air was surprisingly low. The bacteria present for the most part were normal skin flora, and presumably came from the staff rather than the corpses. This conclusion is supported by the following observations:

- Higher counts were found before most necropsies rather than during them.
- The highest overall average counts were found in rooms containing the largest number of people.
- Occasional high counts—for example test 15, related to the pathologist moving across to the side of the sampler.
- Entry of people into the room—for example, students in test 1, increased the count.
- Counts often fell as a necropsy proceeded.

A count of 110/350 l of air is still only 10 per cubic foot—for a long time the standard for operating theatres. The Papworth theatres during an open heart operation contain around 4 per cubic foot; so the average “quiet” ventilated mortuary counts of 1.5–3 compare very favourably. The counts must relate to the smaller number of people and the stillness of the mortuary compared to the operating theatre. These results also bear out the findings of the MRC Working Party on Haemodialysis,⁸ on the difficulty of generating aerosols from blood.

Nevertheless coliforms were found in the air, and

presumably emanated from the bodies. The highest counts were obtained from the patient at Papworth who died of septicaemia with an infarcted bowel, and whose post mortem was done in the original poorly ventilated room; the necropsy on the septicemic patient performed in the upgraded room generated a much smaller aerosol. Although the latter patient died of *Pseudomonas pneumonia*, it is notable that no colony of the infecting organism was picked up from the air.

Raised coliform counts in the Birmingham mortuary (unventilated) related to two patients. No 23 had acute cholecystitis; the observation that counts rose as the organs were being removed suggested an agonal septicaemia. The highest count (109 particles per 350 l) was recorded as the gall bladder pus was being swilled around the dissection table. Patient 24 was examined only 12 min later (when some of the previous aerosol might have persisted). Removal of the intestines produced a count of 76/350 l. This patient turned out to have had diverticulitis and pericolic abscesses. The pressure and speed at which the mortuary work was performed would have ensured a “maximal challenge”; however the highest coliform air count was considerably less than that found in test 4 done at Papworth, before the mortuary was upgraded.

Air counts in the exhaust ducts were performed with the Biotest sampler, which is less efficient at catching small particles. However the Andersen counts revealed that many of the room air particles were large ($>7\mu\text{m}$ diam) and so are likely to have been picked up by the Biotest. This supposition was confirmed by finding that counts in the mortuary exhaust duct at Cambridge were very similar to those found simultaneously in the air of the room itself (whichever sampler was used). The counts in the hospital hall were much greater. Thus it does not seem necessary to filter the duct air. A $5\mu\text{m}$ dust filter would be adequate if filtration was demanded.

The hazards of aerosols during post mortems seem to relate to a few operations—particularly washing the intestines, and (for non-bacterial aerosols)—the use of saws. The settle plate revealed that splashes are probably a much greater hazard, allowing the post mortem room staff to come into direct contact with bacteria. The gall bladder pus for example is likely to have contained 10^6 – 10^7 organisms and flowed across the dissection table, but only 10^2 infected particles were found in 350 l air. This “worst” challenge represents the possibility of inhaling only one coliform containing particle per 7 min at normal rates of respiration. The corollary is that contact with infected surfaces is a potential danger, and so the mortuary should be designed for easy cleaning.

The general background air counts were higher in the unventilated rooms, particularly where there was a lot of movement, as at Birmingham and Hammersmith. An interesting contrast existed between the two, in that at Birmingham four bodies were examined in less time than one at the Hammersmith. The overall counts were lower at Birmingham (although the coliform counts were higher). Quite apart from removing bacterial aerosols, ventilation of the mortuary is required to remove smell, and provide reasonable working conditions for the staff. The ventilation system requires careful design. One of the test mortuaries was equipped with fans that blew air across the ceiling straight to exhaust ducts, thus failing to purge the room efficiently. The exhaust should be low down, or behind dissecting tables. The room also needs to be under a slight negative pressure (unlike the operating theatre) in order to contain odours. The exhaust duct exit might require careful siting for the same reason.

The need for the pathologist to take care with washing and removing organs, particularly intestines, is shown by the counts in Birmingham. The use of a ventilated necropsy table is unlikely to do more than act as an expensive source of room ventilation, because the more hazardous operations—washing the intestines, and close dissection of organs may be done elsewhere. Also some morbid anatomists object to ventilated tables on grounds of difficulty of cleaning. Provision of a small enclosure with extract ventilation may well be appropriate for close working on infected tissue.

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