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Human Immunodeficiency Virus-1 (HIV-1) in the Vapors of Surgical Power Instruments

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Cool vapors and aerosols produced by several common surgical power instruments and hot smoke plumes generated with electrocautery on known HIV-1 innoculated blood were gently bubbled through sterile viral culture media. Tissue culture cells were then added and cell infection was detected by the appearance of HIV-1 P-24 core antigen assayed by ELISA in the culture medium. HIV-1 was cultured from cool aerosols and vapors generated by a 30,000 RPM spinning router tip, an instrument similar to the Midas Rex and the Stryker oscillating bone saw. No infectious HIV-1 was detected in aerosols generated by a Valley Lab electrocautery or with a manual wound irrigation syringe known as a Travenol Uromatic irrigator. We have demonstrated that HIV-1 can remain viable in cool aerosols generated by certain surgical power tools and this raises the possibility of HIV transmission to medical personnel exposed to aerosols similarly generated during the care of HIV infected patients. Further work is required to determine whether such a risk exists but caution should be exercised by those exposed to aerosols generated during procedures on HIV-1 infected patients.

KEY WORDS: aerosols, surgical power tools, hot smoke plumes

INTRODUCTION

Surgeons and other health care workers are routinely exposed to significant and often prolonged aerosols generated by certain orthopedic and surgical procedures on bone, soft tissue, and body fluids. When the tissues contain infectious agents, there is a possibility of transmission of the agent to personnel exposed to the aerosols. For example, papilloma virus DNA has been isolated from laser plumes from papilloma lesions, and nasal papillomas are seen to develop in the noses of physicians and operating room staff cumulatively exposed to laser/papilloma plumes [Garden et al., 1988].

Although HIV-1 appears to be transmitted most frequently by sexual contacts, and by percutaneous and perinatal exposures [Weiss et al., 1985; Melbye, 1986; Henderson et al., 1986; Friedland and Klein, 1986], there is a report of a laboratory worker possibly but not proven to be infected with HIV-1 by aerosols generated by ultracentrifugation or other manipulation of large quantities of cell culture medium containing tissue culture adapted HIV-1 strain HTLV III [Weiss et al., 1988; Barnes, 1988]. That case raises the possibility that individuals might be infected with HIV-1 when performing procedures which strongly aerosolize materials containing infectious HIV. The purpose of this study was to determine if infectious HIV-1 could be isolated from aerosols generated from human blood containing HIV-1 by common orthopedic and surgical procedures known to cause aerosols.

MATERIALS AND METHODS

Four milliliters of human banked O packed red blood cells known to be negative for CMV and HIV antibodies, 4 ml of sterile RPMI 40 with 10% fetal calf serum (culture medium), and 1 ml of culture medium containing 10^5 tissue culture infectious doses (TCID) of HIV-1 (the HTLV III tissue culture adapted strain) were mixed. Such mixtures were individually subjected to electrocautery in the coagulation or the cutting mode, a high speed bone cutting router, an oscillating bone saw, and a wound irrigation syringe jet. Each of these procedures was conducted within a 2,400 ml Becton-Dickinson Vac-Rite operating room suction canister which was in a Biogard (Baker) laminer flow safety cabinet. The sampling-aspiration portal was positioned either 4 in (electrocautery experiments only) or 8 in (all others) above the source and consisted of a small 2 mm inner diameter plastic nipple from a 20 in K-50 Pharmaseal intravenous (IV) extension tube leading to the Luer-lok end of a 10 ml syringe containing 6–7 ml of sterile culture medium. The cool aerosol or hot smoke plume generated by each procedure was suctioned from the cannister via the i.v. extension tube through the

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sterile culture medium in the syringe at approximately 0.8 liter/min. MT-2 cells or human blood mononuclear cells (PBMC) of HIV-1 seronegative patients isolated by Ficoll-Hypaque density gradient centrifugation were then added to the culture medium to a final concentration of 5×10^5 cells per ml. The cells were placed at 37°C in a CO_2 incubator, fed biweekly, and culture medium was tested biweekly for 4 weeks by ELISA for P-24 HIV-1 core antigen (Abbott Laboratories) to assess whether the cells had been infected with HIV-1. For each culture experiment, culture medium containing HIV-1 and medium without virus were separately added to uninfected cells as positive and negative controls, respectively. A positive culture was defined as a P-24 ELISA value greater than 25 pg per ml (above the negative control background value) in two successive biweekly assays of culture medium.

In the electrocautery experiments, either $3 \times 2 \times 1$ cm pieces of sterile thawed fresh frozen human skin and muscle samples or sterile filter paper were subjected to 1–4 min of cutting or coagulation while the HIV-1 containing blood was gently pipetted over the surface. The 2,400 ml canister filled with visible white smoke and the gaseous phase was aspirated for 1–4 min total time, resulting in clearing of the canister.

A cool aerosol was generated with a 30,000 RPM Black and Decker router with a 3/8 in morticing tip protruding 1/2 in inside the end of a 2,400 ml canister by slowly pipetting the HIV-1 containing blood directly onto the horizontal spinning tip for period of 1–3 min. This created an immediate splatter ring around the base and lower third of the canister, while the 2 mm aspiration portal 8 in above the router tip was not visibly splattered. No liquid was observed in the inner lumen of the small tubing through which the gaseous phase was aspirated for 1–4 min.

The Stryker bone saw was used to generate an aerosol by pipetting three 9 ml aliquots of HIV-1 containing blood over the oscillating 1×3 in blade and then partially submerging the oscillating blade in the fluid for 1 min. Total times for aspiration of the gaseous phase were from 1 to 3 min.

The Uromatic irrigator, which is used in some emergency rooms to irrigate small lacerations, is a 10 ml syringe with a 20 gauge laminar flow soft plastic nozzle attached to a one-way valve which allows rapid refilling of the syringe from a reservoir and rapid lavage fluid ejection. Either 10 or 20 ejection repetitions (10 ml each) with the HIV-1 containing blood were performed and the overlying gaseous phase with no visible aerosol was aspirated for 2–3 min.

RESULTS

The results of all experiments are presented in Table I. Positive cultures for HIV-1 were obtained with cool aerosols generated by the effects of the high speed router tip and the oscillating bone saw on an HIV-1 were generated for 1–3 min then aspirated for a total of 1 to 4 min. A total of 5 aerosols were strongly positive for HIV-1 in cell culture with 480 to 642 pg/ml of P-24 HIV-1 antigen detected in culture medium. Four samples were negative. Two of these were the only two tested on PBMC which appeared to be less sensitive for this assay than MT-2 cells. One of the "negative" cultures had an initial P-24 Ag value of 111 pg/ml, but when this level was not sustained the aerosol was scored negative. The longest router and aspiration times (3 and 4 min) were all positive and the negative results occurred with the shortest times (1 or 2 min). One of the four Stryker saw generated aerosols was strongly positive (480 pg/ml). Thus it appears that cool aerosols generated by these surgical power tools can contain infectious HIV-1.

Cool aerosols generated by the manual 10 ml syringe/jet known as a Highland Irrigation device were negative for HIV-1 in two experiments. Similarly, negative results were obtained with the Valley Lab Bovie set for maximal coagulation for times of 1, 2, or 4 minutes in a total of 6 experiments and in 6 experiments with the instrument in the cutting mode. Half the runs were with HIV-1 containing blood on filter paper (used as a burn target in place of tissue) and half were with human skin and muscle specimens. In all of these experiments a visible aerosol or smoke was generated and this was suctioned through the test culture medium.

Four positive and three negative controls for the HIV-1 infectivity assay gave the expected results.

A separate experiment (performed by Don Jewitt et al., submitted) without virus demonstrated that blood aerosols of submicron and micron size were generated and collected by the procedures used in investigating HIV in aerosols. Aerosol particle size distributions measured with a quartz-crystal PC-2H cascade impactor (California Measurements, Inc.) were 0.28–14.0 μm for the Uromatic irrigation system, 0.14–7. μm for the router, 0.07–7.9 μm for the stryker bone saw, and 0.07–2.8 μm for electrocautery.

DISCUSSION

These experiments show that infectious HIV-1 can be isolated from cool aerosols created from blood containing HIV-1 exposed to certain surgical power instruments such as a high speed spinning router (analogous to the Midas Rex) and the Stryker oscillating bone saw. Careful inspection revealed that no liquid or solid material passed through the small (2 mm) diameter 20 in length of tubing used to transfer the aerosol generated by these instruments within the canister to the test culture medium, indicating the virus retained sufficient infectivity in aerosols generated in this way to infect MT-2 cells in culture. Experiments with noninfected blood, utilizing an industrial quartz-crystal impacter, quantitated the large quantity of

TABLE I. Experimental Results

	Procedure	Conditions	Aspiration time (min)	Cell culture type	Maximum P-24 Ag (pg/ml)	Culture result
1	Coag[a]	1 min	1	Buffy coat	0.00	−
2	Coag	1 min	1	Buffy coat	0.00	−
3	Coag	1 min	2	Buffy coat	0.00	−
4	Coag	2 min	2	MT-2	6.50	−
5	Coag	2 min	2	MT-2	6.25	−
6	Coag	4 min	4	MT-2	6.25	−
7	Cutting[b]	1 min	1	Buffy coat	0.00	−
8	Cutting	1 min	1	Buffy coat	0.00	−
9	Cutting	1 min	1	MT-2	10.00	−
10	Cutting	1 min	2	MT-2	22.00	−
11	Cutting	2 min	2	MT-2	11.00	−
12	Cutting	4 min	4	MT-2	10.75	−
13	Router[c]	1 min	1	Buffy coat	0.00	−
14	Router	2 min	2	Buffy coat	111.00	−
15	Router	2 min	2	MT-2	642.30	+
16	Router	2 min	2	MT-2	633.00	+
17	Router	1 min	2	MT-2	6	−
18	Router	2 min	2	MT-2	10.25	−
19	Router	2 min	4	MT-2	480.2	+
20	Router	3 min	4	MT-2	480.2	+
21	Router	2 min	3	MT-2	640.6	+
22	Bone saw[d]	1 min	1	MT-2	4.2	−
23	Bone saw	1 min	1	MT-2	3.75	−
24	Bone saw	2 min	2	MT-2	480.2	+
25	Bone saw	3 min	3	MT-2	3.6	−
26	Irrigator[e]	10 REPS	2	MT-2	22	−
27	Irrigator	20 REPS	3	MT-2	54	−
28	+Control[f]	10^3 HIV/ml	N/A	Buffy coat	642.3	+
29	+Control	10^3 HIV/ml	N/A	Buffy coat	642.3	+
30	+Control	10^3 HIV/ml	N/A	MT-2	642.3	+
31	−Control	0 HIV	N/A	MT-2	0	−
32	−Control	0 HIV	N/A	MT-2	0	−

[a]Coag = Coagulation mode, Valley Lab Electrocautery.
[b]Cutting = Cutting mode, Valley Lab Electrocautery.
[c]Router = 30,000 RPM spinning router tip.
[d]Bone Saw = Stryker Oscillating Bone Saw.
[e]Irrigator = Travenol Uromatic Wound Irrigation Syringe. One Rep = 10 ml.
[f]Controls = Direct innoculation of cultures with blood containing HIV-1 (28) or HIV-1 in culture medium (29,30) or without virus (31,32).

can also be expected to generate cool aerosols less efficiently, did not result in positive cultures as strictly defined here, indicating that aerosols created in this way did not contain enough infectious HIV-1 to be detected in the assay used. The electrocautery in either coagulation or cutting mode created visible smoke plumes which were suctioned through culture medium, but no infectious HIV-1 could be detected, raising the possibility that high temperature of cautery may have inactivated HIV-1.

Although these experiments show that HIV-1 retains infectivity in aerosols generated in certain ways, they do not quantitate the risk of HIV transmission to personnel by such aerosols generated under clinical conditions, e.g., in the operating room. The failure to detect HIV-1 in aerosols generated by certain procedures (e.g., cautery or syringe jet) in our experiments does not exclude the possibility of clinical transmission by such procedures. Several variables could influence the risk of such transmission in a clinical setting. The concentrations of HIV in tissues and body fluids appear to vary widely in different infected patients and HIV is often cell associated. However, extracellular infectious HIV-1 in moderately high concentrations has been detected in plasma of at least some patients [Ernst et al., 1988]. The dose of the wild type HIV strains that might be necessary in an aerosol form to infect via respiratory or mucosal surfaces exposed to such aerosols, and whether such a dose can ever be generated in clinical situations are unanswered questions. Although our experiments raise the possibility that infectious HIV could be present aerosols generated in clinical practice, the large body of epidemiologic data on prevalence of HIV infections in different populations [Weiss et al., 1985; Melbye, 1986; Henderson et al., 1986; Friedland Klein, 1986] would suggest that transmission by aerosols is not common. However, there are no published studies precisely examining medical or den-

tal personnel most heavily exposed to aerosols generated in care of HIV infected patients compared with appropriate controls, and such studies would seem desirable based on our findings. There are studies showing that HBV seroconversion is higher in surgical and dental personnel even controlling for penetrating injuries, a result not inconsistent with an aerosol route of infection in some cases [Dienstag and Ryan, 1982]. An experimental approach that might provide some direct information about aerosol transmission of HIV would be exposure of chimpanzees to aerosols potentially containing HIV generated under conditions simulating different clinical procedures that create aerosols, or the use of some other model system such as simian immunodeficiency virus (SIV) and susceptible non-human primates for such experiments. Further work is also needed to better quantify the nature and size of the aerosol particles which can sustain infectious HIV and the length of time the virus remains viable in aerosol form.

In the absence of definitive studies proving that aerosols in clinical settings pose no risk of HIV transmission to personnel, surgeons, dentists, and others should avoid techniques which generate such aerosols or even smoke plumes with patients known to be infected with HIV. Where such procedures are unavoidable, personnel should consider using high efficiency filtration masks and systems for containing aerosols.

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