INFECTION AND IMMUNITY, Aug. 1980, p. 483-488
0019-9567/80/08-0483/06$02.00/0
Vol. 29, No. 2

Reactivation of Temperature-Sensitive and Non-Temperature-Sensitive Infectious Bovine Rhinotracheitis Vaccine Virus with Dexamethasone

P. P. PASTORET,† L. A. BABIUK,* V. MISRA, AND P. GRIEBEL

Department of Veterinary Microbiology, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE

Latent infections by a temperature-sensitive (*ts*) infectious bovine rhinotracheitis virus vaccine was produced as frequently as by non-*ts* vaccine virus. Thus, virus could be reactivated in seven of eight *ts* vaccinates and six of eight non-*ts* vaccinates after dexamethasone treatment. Virus excretion could be detectable for 1 to 8 days at a level of 2×10^6 to 3×10^8 plaque-forming units per ml of nasal secretions. The reactivated virus was shown to be the same as the original virus used for vaccination by its inability to grow at the restrictive temperature (39°C) as well as by its restriction endonuclease cleavage pattern.

Like most herpesviruses, infectious bovine rhinotracheitis (IBR) has been shown to induce latency after a primary infection (4, 6, 12). Although the actual site of IBR latency and the mechanism(s) involved in reactivating the virus are not fully understood, it is believed that this virus, like other herpesviruses, can remain latent in neurological cells (19). Since the virus can be readily reactivated after dexamethasone treatment (4, 10, 16, 18; P. O. Pastoret, A. Aguilar-Sefieu, G. Burtonboy, J. Mayer, P. Jetteur, and F. Schoenaers, Vet. Microbiol., in press), it is assumed that the immune response is involved either in maintaining the virus in latent state or at least in limiting the amount of virus reexcretion after reactivation.

The extensive use of live attenuated IBR vaccines for controlling IBR infections in cattle (100×10^6 doses in the last 5 years) has raised some concern as to the safety of such vaccines, especially if they themselves produce latency and later revert to virulence. Unfortunately, no one has definitively shown that attenuated IBR vaccines become latent. The main reason for the lack of such definitive proof was that no viral markers were available to differentiate field strains from vaccine strains. The recent development of temperature-sensitive (*ts*) IBR vaccine (23) and restriction endonuclease fingerprinting techniques has provided us with such markers (17). Using these techniques we have attempted first to determine whether vaccine virus can induce latency and can be reactivated. Second, we wish to determine whether *ts* vaccines can prevent establishment of infection with virulent field strains. Thus, the ideal vaccine would be one that does not induce latency and also prevents establishment of a latent infection with wild-type virus. The best possible candidate for such a vaccine appears to be appropriate *ts* vaccines, since theoretically they would be restricted to the surface epithelial cells of the upper respiratory tract and never get established in the neurological cells.

The present report describes our attempts to reactivate *ts* and non-*ts* IBR vaccine from animals by the use of dexamethasone, as well as to assess various immune parameters after dexamethasone treatment in an attempt to understand the mechanisms whereby the immune response can prevent reexcretion of virus in nature.

MATERIALS AND METHODS

Cells and virus. Georgia bovine kidney cells were cultured in Eagle minimal essential medium containing 10% fetal bovine serum as described previously (1). Each liter was supplemented with 2 mM glutamine (no. 503, GIBCO Laboratories, Grand Island, N.Y.), 25 mg of gentamicin (Schering Diagnostics), 2.5 g of sodium bicarbonate, and nonessential amino acids (no. 114, GIBCO).

ts IBR virus vaccine (Norden) and non-*ts* vaccine virus (Connaught) were cultured from commercial vaccines by infecting confluent GBK monolayers with 1 ml of the reconstituted vaccine, and the virus was allowed to absorb for 1 h before the addition of fresh minimum essential medium-5% fetal bovine serum. The *ts* vaccine-infected cultures were incubated at 35°C, and the Connaught vaccine (Con-IBR) was cultured at 37°C until they exhibited extensive cytopathology. All the cells and the culture fluids were harvested and subjected to two freeze-thaw cycles before removal of cellular debris by centrifugation (1,000 × *g* for 10 min). This cell-free preparation was used to

† Permanent address: Laboratory of Virology, Faculty of Veterinary Medicine U. Lg., 1970 Brussels, Belgium.

vaccinate animals as described below. Strain 108, a virulent IBR isolate used for challenge experiments, was obtained from C. Darcel, le Q, Animal Disease Research Institute, Lethbridge, Alberta. It was passaged 2× in our laboratory as previously described (13).

Animals. Nine-month-old, healthy, male and female Hereford cattle, free of IBR virus-neutralizing antibody, were randomly divided into two groups of eight animals each (Fig. 1). One group was vaccinated intranasally with *ts* IBR and the other group was vaccinated with Con-IBR (5×10^6 plaque-forming units per animal).

Five and six weeks later, nasal swabs and blood samples were collected from all animals for serum neutralization, antibody-dependent cell cytotoxicity, and blastogenesis assays to obtain a background level of antiviral activity as well as for a hematological profile of each animal (3, 13, 15, 21). Animals were then treated for 5 consecutive days with dexamethasone (0.1 mg/kg of body weight). During the last 3 days of dexamethasone injection, the animals were given an intramuscular injection of antibiotics (Pen-Strep Roger/STB at recommended doses) to prevent possible septicemia. Nasal swabs were obtained daily for virus isolation, and blood samples were collected for hematological and immunological studies (Fig. 1).

Three weeks after the end of the first dexamethasone treatment, the *ts* group was challenged with virulent 108 virus and the Con-IBR group was treated with dexamethasone as described above. Both groups were once again monitored for virus excretion and immunological responses. Four weeks after challenge with virulent 108 virus, the *ts* IBR group was once again treated with dexamethasone and monitored for virus excretion and immunological responses (Fig. 1).

Virus isolation. Virus was eluted from nasal swabs (Falcon no. 2009) by blending the swab in a Vortex mixer in a 10-fold volume of minimum essential medium. The amount of virus present in each sample was quantitated by plaquing 10-fold dilutions of each sample in microtiter plates as described previously (3).

Neutralization and antibody-dependent cell cytotoxicity assays. Antibody levels in nasal secretions and serum or plasma were determined by standard neutralization assays as described previously (3). Antibody-dependent cell cytotoxicity assays were performed as described previously (14). The target cells were IBR-infected ^{5}Cr-labeled GBK cells, and the effector cells were bovine mammary gland polymorphonuclear cells (22). The polymorphonuclear-to-target cell ratio was 50:1.

Blastogenesis. Peripheral blood lymphocytes were prepared as described previously (14) and incubated in the presence of ultraviolet-irradiated IBR antigen for 96 h before measuring the level of stimulation (13).

Hematological studies. Blood was collected into vacuum tubes (Venoject, KT) containing ethylenediaminetetraacetic acid (EDTA). Blood smears were prepared within 1 h of collection and stained with Wright Giemsa in an Ames-Tek automatic staining machine. Differential blood counts were performed by two different investigators. Other parameters (packed cell volume, hemoglobin, erythrocytes, leukocytes, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration)

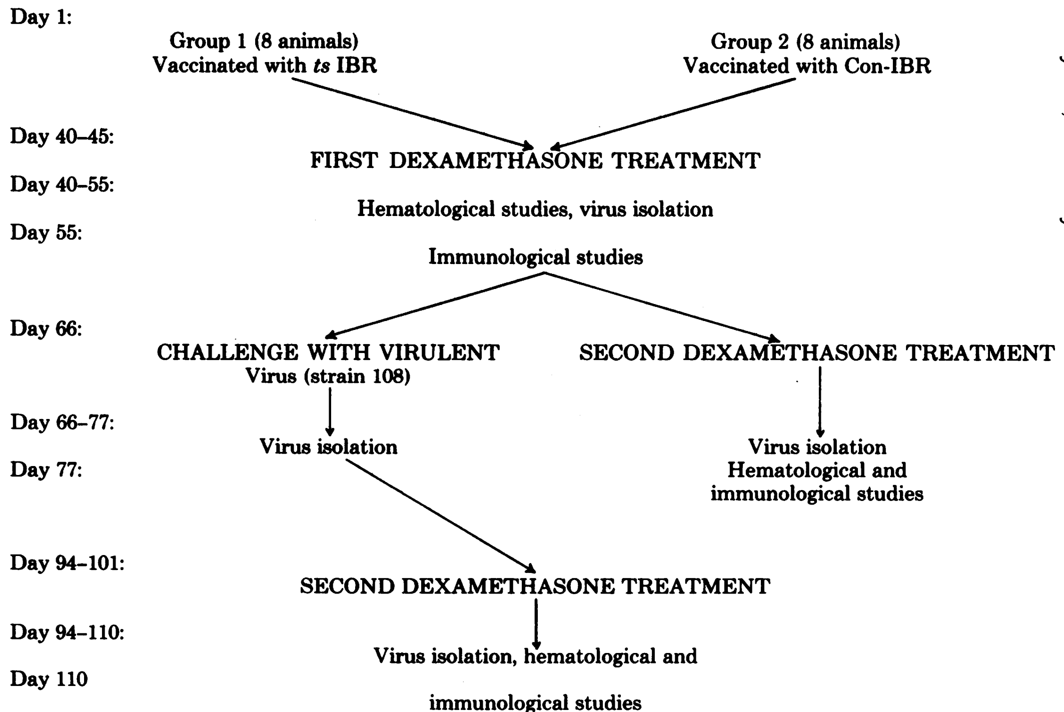

FIG. 1. *Experimental design.*

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE

were assessed in a model S Coulter Counter equipped with appropriate attachments.

Restriction endonuclease analysis of IBR isolates. Viral deoxyribonucleic acid (DNA) was purified by the technique of Pignatti et al. (11). GBK cells in 100-mm-diameter petri dishes were infected with virus and incubated at 35°C. When a majority of cells in the culture displayed cytopathology, cells were collected, washed 2× with phosphate-buffered saline (PBS) and frozen at −70°C. To extract DNA, the cells were thawed and suspended in 1.8 ml of lysing solution [0.25% Triton X-100, 10 mM EDTA, and 10 mM tris(hydroxymethyl)aminomethane (Tris)-hydrochloride, pH 7.9]. After standing at room temperature for 10 min with gentle mixing, NaCl was added to a final concentration of 200 mM. The tube was inverted a few times and centrifuged at 1,000 × *g* at 4°C for 10 min. DNA in the supernatant was deproteinized by incubating overnight with pronase (100 μg/ml) and sodium dodecyl sulfate (0.2%) followed by extraction with phenol and chloroform (9). DNA was then precipitated twice with ethanol and dissolved in 200 μl of 10 mM Tris (pH 7.8)-10 mM NaCl-0.5 mM EDTA. The DNA solution (75 μl) was then digested with the restriction endonucleases *Hin*dIII or *Eco*RI. For *Eco*RI, 50 μl of reaction mixture contained viral DNA, 100 mM Tris (pH 7.5), 50 mM NaCl, 10 mM $MgCl_2$, and 5 U of *Eco*RI. The reaction mixture for *Hin*dIII was comprised of viral DNA, 50 mM NaCl, 6 mM Tris (pH 7.5), 6 mM $MgCl_2$, 0.1 mg of bovine serum albumin per ml, and 8 U of *Hin*dIII. After incubating for 1 h at 37°C, the reaction was terminated by the addition of 50 μl of BJ (100 mM EDTA, 5% sodium dodecyl sulfate, 25% glycerol, and 0.025% bromophenol blue) and heating at 65°C for 10 min.

A 50-μl amount of DNA samples was loaded onto wells in a horizontal 0.5% agarose slab and electrophoresed for 3 h at 150 V. The electrophoresis buffer contained 90 mM Tris (pH 7.9), 90 mM boric acid, and 2.5 mM EDTA. After staining gels with 4 μg of ethidium bromide per ml of electrophoresis buffer, gels were illuminated with an ultraviolet light and photographed with a Polaroid MP4 camera with Polaroid Ty55 P/N film.

RESULTS

Reactivation of IBR virus with dexamethasone and characterization of reactivated virus. After the first dexamethasone treatment, six of eight Con-IBR animals and seven of eight *ts* IBR animals excreted virus. However, all animals were probably latently infected and reexcreted virus, since all animals exhibited a rise in specific anti-IBR antibody levels. Furthermore, animals that did not excrete detectable virus after the first dexamethasone treatment did so after a second treatment of dexamethasone. In animals where virus excretion was detectable, virus excretion began on the last day of dexamethasone treatment (5 days after initiation of treatment) and lasted for up to 8 days. Although some animals in both groups shed up to 8 logs of virus per ml of nasal secretions, the *ts* IBR-vaccinated animals on the average excreted more virus (5.25 versus 3.75 logs) over a longer period of time, suggesting that *ts* IBR vaccines produced latency as readily as did regular vaccines (Table 1).

In an attempt to prove that the excreted virus was *ts* and not a field strain of virus to which the animals could have been exposed accidently, we tested the excreted virus for its ability to grow at 39°C. Table 2 illustrates that the virus isolated from the *ts* IBR-vaccinated animals was indeed *ts*, since the plaquing efficiency was very low at 39°C.

To confirm that the virus isolated for the *ts* IBR-vaccinated animals was indeed of the *ts* genotype, we exploited the technique of endonuclease cleavage mapping. Electrophoresis after cleavage with the enzyme *Eco*RI separates

TABLE 1. *Reactivation of IBR vaccine virus by dexamethasone treatment*

Vaccine group	No. of animals excreting	Primary[a] excretion level	Length of excretion (days)	Secondary[b] excretion level
Con-IBR	6/8	2×10^2–3×10^8 (3.75)[c]	2–5 (3.4)[d]	2×10^2–1×10^4 (2.6)[c]
ts IBR	7/8	3×10^3–2×10^8 (5.25)	1–8 (5.3)	

[a] The level of IBR excretion (plaque-forming units per milliter of nasal secretions) after the first series of dexamethasone treatments

[b] The level of IBR excretion (plaque-forming units of nasal secretions) after the second series of dexamethasone treatments.

[c] Value in brackets represents the mean level of excretion the day after dexamethasone treatment was stopped.

[d] Value in brackets represents the mean excretion time in days for all animals that excreted virus.

TABLE 2. *Properties of dexamethasone-reactivated IBR virus*

Virus	Virus yield[a]		
	34°C	39°C	EOP (39°/34°C)[b]
Wild type (strain 108)	1.7×10^6	2.1×10^6	>1
Con-IBR vaccine	6×10^6	1.8×10^7	>1
ts IBR vaccine	3×10^6	1.2×10^2	0.4×10^{-4}
Reactivated Con-IBR	4×10^6	1.2×10^7	1
Reactivated *ts* IBR			
Animal no. 4	3.5×10^6	2×10^2	0.57×10^{-4}
Animal no. 18	1.1×10^6	$<10^2$	$<10^{-4}$
Animal no. 19	2.25×10^6	$<10^2$	$<10^{-4}$
Animal no. 23	8.5×10^6	$<10^2$	$<10^{-4}$
Animal no. 25	3.5×10^4	$<10^2$	$<10^{-4}$
Animal no. 27	8.5×10^5	1×10^2	2×10^{-4}
Animal no. 28	4×10^4	$<10^2$	$<10^{-4}$

[a] Confluent GBK cells were infected with various IBR isolates at a multiplicity of infection of 0.1. One group of cultures was incubated at 34°C, and the other was incubated at 39°C. Twenty-four hours later the cultures were harvested, and the yield of virus (plaque-forming units per milliliter) was determined. Titration was at 34°C.

[b] Efficiency of plating (EOP) at 39°C versus 34°C was determined by dividing the virus yield at 39°C by the virus produced at 34°C.

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE

DNA from *ts* IBR into seven bands which range from 35 to 4.5 megadaltons (Table 3). Each band appears to comprise one fragment, and the fragments are present in the digest in unimolar quantities. In contrast, Con-IBR yields six bands, band C + D being a composite of two fragments. The enzyme *Hin*dIII generates 12 bands from *ts* IBR. Bands C and D are present in 0.5 M amounts, band F + G comprises two fragments, and the remaining bands appear to be unimolar. The *Hin*dIII digest of Con-IBR differs from IBR (*ts*) in that band I is replaced by a lower-molecular-weight band K. In all cases the endonuclease cleavage pattern of the *ts* reactivated virus was similar to the original *ts* vaccine, whereas the Con-IBR vaccine virus and virus reactivated from Con-IBR-vaccinated animals were different from the *ts* IBR (Fig. 2).

TABLE 3. *Molecular weights of restriction endonuclease digests of ts IBR and Con-IBR*

Enzyme	Fragments		Mol wt ($\times10^6$)
	Con-IBR	*ts* IBR	
*Eco*RI	A	A	35
	B	B	13.7
		C	11.95
	C+D		11.6
		D	11.2
	E	E	9.69
	F	F	6.02
	G	G	4.5
*Hin*dIII	A	A	12.88
	B	B	12.3
	c	c	10.9
	d	d	10.44
	E	E	9.45
	F+G	F+G	8.3
	H	H	5.9
		I	5.66
	J	J	5.0
	K		4.79
	L	L	2.2
	M	M	1.42

Immune status of animals before and after reactivation. Since dexamethasone treatment reactivated virus, attempts were made at determining whether such treatment altered the level of immunity to IBR virus. In both groups of animals, serum-neutralizing antibodies and target cell-sensitizing antibodies, as detected by virus neutralization and antibody-dependent cell cytotoxicity, were elevated 7 days after termination of dexamethasone treatment (Fig. 3 and 4). These results indirectly confirm that virus excretion occurred.

In an attempt to determine whether *ts* IBR vaccine could prevent infection with a virulent field strain, the *ts* IBR-vaccinated animals were infected with a virulent strain (108) 3 weeks after dexamethasone treatment. All eight animals excreted virus for up to 6 days after challenge. These animals exhibited typical IBR lesions in the nasal passages but did not show severe lower respiratory involvement. These animals exhibited a very dramatic increase in the level of immunity after challenge (Fig. 4). If this group was treated with dexamethasone a second time, 4 weeks after challenge, no virus excretion could be detected. Furthermore, there was not a significant increase in the level of immunity of the group as a whole, but some individual animals expressed a significant increase. The possible reason for the lack of detectable virus excretion could be that the level of local antibody was of sufficient magnitude that it could neutralize all the virus that was reactivated. Thus, the nasal secretions of all animals could neutralize in excess of 5 logs of virus in vitro.

DISCUSSION

Dexamethasone treatment of cattle previously vaccinated with IBR vaccines resulted in a rapid alteration in the number and relative proportions of peripheral blood leukocytes and subsequent reactivation of IBR virus. The frequency of reactivation of virus was the same whether

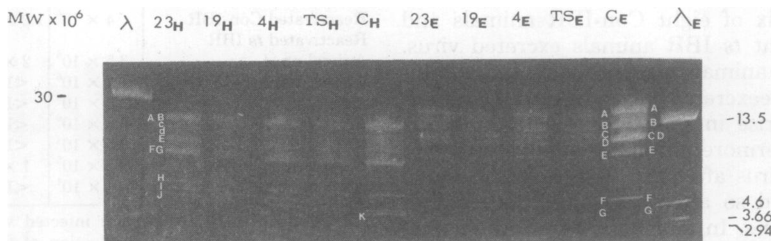

FIG. 2. *Electrophoretic analysis of DNA from IBR vaccines; Connaught (C), ts, Norden (TS), and virus isolated after dexamethasone reactivation from three animals (animal no. 4, 19, and 23). Purified DNA samples were digested with the restriction endonucleases EcoRI (E) and HindIII (H). After electrophoresis on 0.5% agarose gels, the gels were stained with ethidium bromide and fluorographed under ultraviolet light. The virus isolates were obtained from nasal secretions of animals that had been vaccinated with ts IBR vaccine and treated with dexamethasone 40 days later, as shown in Fig. 1.*

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE

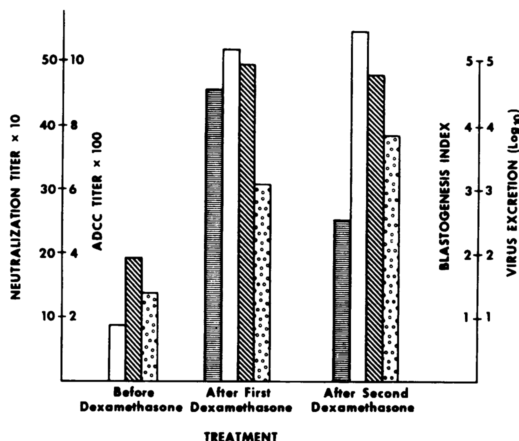

FIG. 3. *Level of virus excretion and immune responses of Con-IBR-vaccinated animals treated with dexamethasone. Animals were vaccinated intranasally with 2 × 10^6 plaque-forming units of Con-IBR virus. Six weeks later they were treated with 0.2 mg of dexamethasone per kg and the level of virus excretion (▤) was determined. One week after termination of dexamethasone treatment, immune responses, serum neutralization (□), antibody-dependent cell cytotoxicity (▨), and blastogenesis (▩) response to IBR virus were assessed.*

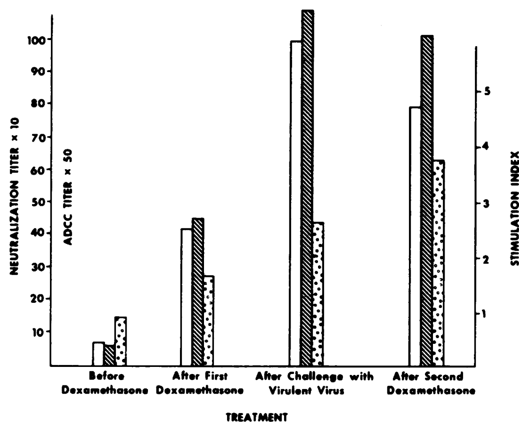

FIG. 4. *Immune status of ts-IBR-vaccinated animals after various treatments. Animals were vaccinated intranasally with 2 × 10^6 plaque-forming units of ts-IBR virus. Six weeks later they were treated with 0.2 mg of dexamethasone per kg (first dexamethasone). Three weeks later they were challenged with wild-type virulent virus (strain 108) followed by a second dexamethasone treatment 4 weeks after challenge. One week after dexamethasone treatment or challenge, the level of immunity of each animal was tested by serum neutralization (□), antibody-dependent cell cytotoxicity (▨), and blastogenesis (▩).*

animals were vaccinated with *ts* IBR or non-*ts* Con-IBR (Table 1). These results suggest that both types of vaccines can establish latency with the same frequency. Furthermore, the high frequency of reactivation (80 to 100%) with the vaccines suggests that IBR vaccines are as good at inducing latent infections as is virulent virus. In an attempt to prove that the virus excreted was indeed vaccine virus and not field strains of virus to which the animals were accidently exposed, we used two approaches. First, the viruses isolated from animals were tested for their ability to grow at restricted temperatures (39°C). In all cases the virus reactivated from *ts* IBR-vaccinated animal was *ts*, whereas the virus isolated from Con-IBR-vaccinated animals was not *ts* (Table 2). Secondly, the endonuclease cleavage maps of the reactivated virus matched the endonuclease cleavage maps of the vaccine used to vaccinate the animals. The latter findings suggest that the virus that induces latency and is later reactivated is not a mutant but is representative of the general population used to infect the animal. Whether its genotype and virulence changes with repeated reactivation or whether recombination can occur with virulent field strains was not possible to determine, since virus could not be reactivated after infection of *ts*-vaccinated animals with virulent virus. The lack of ability to reactivate virulent or *ts* virus from these animals could possibly be due to the high level of immunity to IBR virus. Since it is postulated that the immune response is not only involved in recovery but also is maintaining herpesvirus latency (2, 4, 7, 20), it is possible that if the level of immunity decreased with time, reactivation and reexcretion may occur. If this occurs, then it should be possible to determine whether recombination between vaccine virus and field strains occurs.

Even though the mean titer of virus excretion by Con-IBR-vaccinated animals was slightly lower (3.75 logs) than *ts* IBR-vaccinated animals (5.25 logs), some animals in both groups excreted in excess of 8 logs of virus per ml of nasal secretions. The possible reason for the slight increase in the mean level of excretion in the *ts* IBR animals is that these animals had a lower level of immunity after primary vaccination. The observation that the animals which excreted the highest level of virus were the ones that had the lowest immune response supports the suggestion that latency and reactivation are influenced by the immune status of the animal. Further support for the suggestion that the immune response influenced the level and length of excretion was the observation that after the first episode of excretion the immune response was elevated. Thus, the amount of replication and excretion was limited after a second dexamethasone treatment such that not only was there less virus excreted (2.6 logs) but it was excreted for a much shorter time (1.5 days) in Con-IBR animals. If the immune response was boosted

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE

even higher by infection with virulent virus, no shedding was detectable after the second dexamethasone treatment.

Since dexamethasone is not a very long-acting immunosuppressive drug, discontinued use results in a return to normal, and the immune response can then control both intracellular and extracellular spread of virus and shedding stops. Since immunosuppression is short lived, viral antigens present can act as a booster to the immune response, and therefore this would explain the increase in immunity after dexamethasone treatment and virus reactivation. Presumably, after numerous reactivation cycles, the level of local antibodies present is so high that even though reactivation occurs, infectious virus is rapidly neutralized and excretion cannot be detected.

Although our present results illustrate that the presently licensed *ts* IBR vaccine induces latency, we feel that it should be possible to produce other *ts* mutants which do not produce latency. Such latency-negative mutants have been described for *ts* mutants of herpes simplex (5, 8). If such mutants of IBR are found and they can provide adequate immunity, then they would be the ideal ones to use as vaccines to control IBR. Furthermore, an analysis of the *ts* lesion and its comparison to herpes simplex virus type 1 latency-negative mutants should provide some information as to the genes required for induction of herpesvirus latency. Such experiments are presently in progress.

ACKNOWLEDGMENTS

Our thanks to Joyce Sander for typing the manuscript.

Financial support was provided for by grants from the Medical Research Council of Canada and Farming for the Future and Fonds National de la Recherche Scientifique (F.N.R.S.) of Belgium.

LITERATURE CITED

1. **Babiuk, L. A., and B. T. Rouse.** 1976. Immune interferon production by lymphoid cells: role in the inhibition of herpesviruses. Infect. Immun. **13**:1567–1578.
2. **Babiuk, L. A., and B. T. Rouse.** 1979. Immune control of herpesvirus latency. Can. J. Microbiol. **25**:267–274.
3. **Babiuk, L. A., R. C. Wardley, and B. T. Rouse.** 1975. Defense mechanisms against bovine herpesvirus. Relationship of virus-host cell events to susceptibility to antibody-complement cell lysis. Infect. Immun. **12**:958–963.
4. **Davies, D. H., and L. E. Carmichael.** 1973. Role of cell-mediated immunity in the recovery of cattle from primary and recurrent infections with infectious bovine rhinotracheitis virus. Infect. Immun. **8**:510–518.
5. **Gerdes, J. C., H. S. Marsden, M. L. Cook, and J. G. Steven.** 1979. Acute infection of differentiated neuroblastoma cells by latency-positive and latency-negative herpes simplex virus ts mutants. Virology **94**:430–441.
6. **Gibbs, E. P. J., and M. M. Rweyemamu.** 1977. Bovine herpesviruses. Part 1. Vet. Bull. **47**:317–343.
7. **Lehner, T., J. M. A. Wilton, and E. J. Shillitoe.** 1975. Immunological basis for latency, recurrences and putative oncogenicity of herpes simplex virus. Lancet **ii**:60–62.
8. **Lofgren, K. W., J. G. Steven, H. S. Maroden, and J. H. Subak-Sharpe.** 1977. Temperature-sensitive mutants of herpes simplex virus differ in the capacity to establish latent infections in mice. Virology **76**:440–443.
9. **Misra, V., M. T. Muller, J. K. Chantler, and J. B. Hudson.** 1978. Regulation of murine cytomegalovirus gene expression. I. Transcription during productive infection. J. Virol. **27**:263–268.
10. **Notter, M. F. D., and J. J. Docherty.** 1978. Steroid hormone alteration of herpes simplex type 1 replication. J. Med. Virol. **2**:247–252.
11. **Pignatti, P. F., E. Cassai, G. Meneguzzi, N. Chenciner, and G. Milanesi.** 1979. Herpes simplex virus DNA isolation from infected cells with a novel procedure. Virology **93**:260–264.
12. **Plowright, W.** 1978. Vaccination against diseases associated with herpesvirus infections in animals: a review, p. 965–980. *In* G. de the W. Herle and F. Rapp (ed.), Oncogenesis and Herpesviruses III. IARC Scientific Publication no. 24. International Agency for Research on Cancer, Lyon, France.
13. **Rouse, B. T., and L. A. Babiuk.** 1974. Host defense mechanisms against infectious bovine rhinotracheitis virus: in vitro stimulation of sensitized lymphocytes by virus antigen. Infect. Immun. **10**:681–687.
14. **Rouse, B. T., and L. A. Babiuk.** 1974. Host responses to infectious bovine rhinotracheitis virus. III. Isolation and immunological activities of bovine T lymphocytes. J. Immunol. **113**:1391–1398.
15. **Rouse, B. T., R. C. Wardley, and L. A. Babiuk.** 1976. Antibody-dependent cell-mediated cytotoxicity in cows: comparison of effector cell activity against heterologous erythrocytes and herpesvirus infected bovine target cells. Infect. Immun. **13**:1433–1441.
16. **Sheffy, B. E., and D. H. Davies.** 1972. Reactivation of a bovine herpesvirus after corticosteroid treatment. Proc. Soc. Exp. Biol. Med. **140**:974–976.
17. **Skare, J., and W. C. Summers,** 1977. Structure and function of herpesvirus genomes. II. Eco RI Xbal and Hind III endonuclease cleavage sites on herpes simplex type 1 DNA. Virology **76**:581–595.
18. **Snowdon, W. A.** 1965. The IBR-IPV virus: reaction to infection and intermittent recovery of virus from experimentally infected cattle. Aust. Vet. J. **41**:135–142.
19. **Stevens, J. G.** 1978. Latent characteristics of selected herpesvirus. Adv. Cancer Res. **26**:227–256.
20. **Steven, J. G., and M. L. Cook.** 1974. Maintenance of latent herpetic infection. An apparent role for antiviral IgG. J. Immunol. **113**:1685–1693.
21. **Wardley, R. C., L. A. Babiuk, and B. T. Rouse.** 1976. Polymorph-mediated antibody-dependent cytotoxicity modulation of activity by drugs and immune interferon. Can. J. Microbiol. **22**:1222–1228.
22. **Wardley, R. C., B. T. Rouse, and L. A. Babiuk.** 1976. The mammary gland of the ox: a convenient source for the repeated collection of neutrophils and macrophages. RES J. Reticuloendothel. Soc. **19**:29–36.
23. **Zygraich, N., E. Vascoboinic, and C. Huygelen.** 1974. Replication of a temperature sensitive mutant of infectious bovine rhinotracheitis virus in the tissues of inoculated calves. Zentralbl. Veterinaermed. Reihe B **21**: 138–144.

Downloaded from http://iai.asm.org/ on February 16, 2018 by UNIV DE LIEGE