Comparison of Susceptibilities of Varicella-Zoster Virus and Herpes Simplex Viruses to Nucleoside Analogs

HARUHIKO MACHIDA
Research Laboratories, Yamasa Shoyu Co. Ltd., Choshi-shi, Chiba-ken, 288 Japan
Received 6 June 1985/Accepted 2 December 1985

The susceptibilities of varicella-zoster virus (VZV) and herpes simplex virus type 1 (HSV-1) and type 2 (HSV-2) to 17 nucleoside analogs were compared by a plaque reduction assay with human embryonic lung fibroblast cells. The susceptibility of VZV to certain nucleoside analogs was different from that of HSV-1. Against VZV the 5-halogenonucleosyl-arabinosyluracils were the most potent of the compounds tested.

Varicella-zoster virus (VZV) is capable of inducing a virus-specific thymidine kinase (TK) (2, 9) which seems to resemble the herpes simplex virus (HSV)-induced TK in substrate specificity (4). Therefore, one might expect VZV to be susceptible to nucleoside analogs which are active against HSV. Indeed, the in vitro inhibition of VZV replication by a number of antiviral agents has been reported (4, 6, 13). However, these studies did not involve side-by-side assessments of the inhibition of HSV replication. This report involves a direct comparison of the susceptibilities of HSV and VZV to a wide variety of nucleoside analogs. Since cell lines and assay methods can affect the relative susceptibilities of viruses to antiviral agents (3, 5, 11), we used the same cell culture system and assay method in our comparison. Since both HSV and VZV form clear plaques on human embryonic lung fibroblast (HEL-F) cells, we used these cells and a plaque reduction assay to determine the susceptibilities of HSV type 1 (HSV-1), HSV type 2 (HSV-2), and VZV to 17 nucleoside analogs.

HEL-F cells, strain HAIN-55 (10), kindly supplied by H. Okumura, National Institute of Health of Japan, Tokyo, were used in this study. The level of passage of the cells was 25 to 33 population doublings. Three strains of HSV-1 and three strains of HSV-2 were used as stock strains (7). Three clinical isolates which had been typed as HSV-1 were kindly supplied by T. Kurimura, Tottori University School of Medicine, Yonago, Japan, and by K. Hayashi, Koriyama Institute of Medical Immunology, Koriyama, Japan. Seven strains of VZV (6) and strains CaQu, Batson, and K9 were used. The latter three strains were kindly supplied by S. Shigeta, Fukushima Medical College, Fukushima, Japan, and M. Takayama, National Institute of Health of Japan. These VZV strains were passaged 6 to 20 times in HEL-F cells, except that strains Ohtomo, CaQu, and Batson were passaged more than 100 times and strain K9 was passaged 45 to 48 times. The plaque reduction assay was carried out as described previously (6,7), except that in some experiments the HSV-infected cultures were overlaid with maintenance medium containing 0.8% methylcellulose (3,500 to 5,600 centipoise); Nakarai Chemicals) in place of 0.5% Noble agar (Difco Laboratories) and 50 μg of DEAE-dextran per ml and that if necessary, HSV- and VZV-infected cultures were stained with 1% crystal violet solution. The 50% inhibitory doses (ID50s) of the test compounds for exponentially growing HEL-F cells were determined as described previously (9).

The compounds evaluated included the following: 1-β-D-arabinofuranosyl-E-5(2-bromovinyl)uracil (BV-araU), 1-β-D-arabinofuranosyl-E-5(2-chlorovinyl)uracil (CV-araU), 1-β-D-arabinofuranosyl-E-5(2-iodovinyl)uracil (IV-araU), and 1-β-D-arabinofuranosyl-E-5(2-bromovinyl)uracil-5′-monophosphate (BV-araUMP) (7, 8); 1-β-D-arabinofuranosyl-5′-vinyluracil (vinyl-araU), 5-hydroxy-2′-deoxyxuridine (OH-dUrd), 5-methoxy carbonylmethyl-2′-deoxyuridine (MCM-dUrd), and 5-acetyl-2′-deoxyuridine (acetodUrd) (12); arabinofuranosylthymine (araT) and 5-iodo-2′-deoxyuridine (I-dUrd) (both from Yamasa Shoyu Co., Ltd.); 1-β-D-arabinofuranosyl-5-ethyluracil (ethy1araU), E-5(2-bromovinyl)-2′-deoxyuridine (BVdU), and 1-(2-deoxy-2-fluoro-β-D-arabinofuranosyl)-5′-vinyluracil (FVAdU) (all synthesized by T. Ikeda and T. Yamaguchi, Yamasa Shoyu Co. Ltd., Choshi-shi, Chiba-ken, Japan); 5-ethyl-2′-deoxyuridine (EDU) (kindly supplied by K. K. Gauri, Universitat Hamburg, Hamburg, Federal Republic of Germany); 1-(2-deoxy-2-fluoro-β-D-arabinofuranosyl)-5′-iodocytosine (FIAC) and 1-(2-deoxy-2-fluoro-β-D-arabinofuranosyl)-5′-iodocytosine (FIAC) and 1-(2-deoxy-2-fluoro-β-D-arabinofuranosyl)-5′-methyluracil (FMAU) (both kindly supplied by J. J. Fox, Sloan-Kettering Institute, New York, N.Y.); and acyclovir (kindly supplied by W. G. Wilson, Nippon Wellcome Co. Ltd., Shinoo, Osaka, Japan).

All of the nucleoside analogs tested (Table 1) were active against the various strains of HSV-1, including the clinical isolates, the 5-halogenonucleosyl-arabinosyluracils (XV-araUs), BVdU, the 2′-fluoro-arabinosylpyrimidine nucleosides (F-araPy), and acyclovir were especially active. OH-dUrd, araT, FIAC, FMAU, and acyclovir were almost as active against HSV-2 as against HSV-1. In contrast, HSV-2 was much less susceptible to BVdU, vinyl-araU, XV-araU, BV-araUMP, ethyl-araU, and acetodUrd than was HSV-1. The 50% plaque reduction doses of the latter compounds for HSV-2 were generally two or more orders of magnitude greater than those for HSV-1. HSV-2 strains were, on the average, 10 to 30 times less susceptible than were HSV-1 strains to I-dUrd, MCM-dUrd, and FVAdU. Although the compounds varied enormously in potency, there was little variation in the susceptibilities of strains of either HSV-1 or HSV-2, including the clinical isolates, to a particular compound. VZV was more susceptible than HSV-1 to XV-araUs and BV-araUMP and, like HSV-1, was susceptible to the other nucleoside analogs, with the exception of ethyl-araU. However, VZV was less susceptible than HSV-1 to EDU, vinyl-araU, ethyl-araU, acetodUrd, and acyclovir. Overall, the variation in the susceptibilities of...
different strains of VZV to a particular compound was relatively great.

The inhibition of cell growth by XV-araUs, BV-araUMP, OH-dUrd, aceto-dUrd, and ethyl-araU was less than 50% at a drug concentration as high as 800 µg/ml. The antiviral indexes of XV-araUs and BV-araUMP for HSV-1, calculated as the ID₅₀ for HEL-F cells divided by the 50% plaque reduction dose for HSV-1, were greater than 50,000, and those for VZV were greater than 1,900,000. These values were the highest among those of the compounds tested. BVDU, MCM-dUrd, araT, vinyl-araU, and acyclovir also had low inhibitory action on cell growth (ID₅₀, 100 to 650 µg/ml), whereas F-araPyr and I-dUrd were found to have inhibitory action. The antiviral indexes of F-araPyr for HSV were less than 1,000.

The activity of nucleoside analogs against VZV was expected since, like HSV-1 and HSV-2, VZV is capable of inducing virus-specific TK (2, 9). Specific phosphorylation in virus-infected cells is a general phenomenon that has been observed for all selective inhibitors of HSV-1, HSV-2, and VZV. Indeed, all compounds tested in this study, except I-dUrd, have been shown to be selective (7, 12). HSV-induced TK has broad substrate specificity and can phosphorylate many nucleoside analogs (1). If VZV-induced TK has the same substrate specificity and ability to phosphorylate monophosphate nucleoside derivatives as does HSV-1-induced TK, VZV and HSV-1 might be equally susceptible to each compound. However, we found some differences between the susceptibilities of HSV-1 and VZV to the 17 nucleoside analogs tested. (i) VZV and HSV-1 were almost equally susceptible to compounds such as F-araPyr, araT, and 5-substituted deoxyuridines, with the exception of EDU and aceto-dUrd. (ii) VZV was much more susceptible than HSV-1 to XV-araUs and BV-araUMP. (iii) VZV was markedly less susceptible than HSV-1 to the other compounds, including acyclovir, aceto-dUrd, EDU, ethyl-araU, and vinyl-araU. Furthermore, VZV was less susceptible than HSV-2 to ethyl-araU, EDU, and acyclovir, and both VZV and HSV-2 were less susceptible than HSV-1 to nucleoside analogs having an ethyl or a vinyl residue at the C-5 position of the pyrimidine base.

LITERATURE CITED


11. Reuschläger, J., G. Herrmann, D. Bärwolf, B. Schwarz, D.
Cech, and P. Langen. 1983. Antiherpes activity of \((E)-5-(2-
\text{bromovinyl})-\) and 5-vinyl-1-\(\beta\)-d-arabinofuranosyluracil and some other 5-substituted uracil arabinosyl nucleosides in two different cell lines. Antiviral Res. 3:175–187.
