



Fig. 4. HeLa cells after combined action of ultrasound and cytostatics. Exposures, concentrations and incubations the same as in Figs. 2 and 3. a) microtubules - ultrasound and cycloplatin, b) microfilaments - ultrasound and cycloplatin, c) microtubules - ultrasound and methotrexate, d) microfilaments - ultrasound and methotrexate

of pathological features. Similar alterations have been demonstrated after the action of other stress factors, such as thermal shock, UV radiation, and the lack of oxygen, in other experiments (Cachon et al., 1981; Veselská and Janisch, 1998). Variable effects of cytostatic drugs described by Wolf et al. (1995) in other cell lines were demonstrated in our experiments, too. It seems, therefore, that changes observed in this study can be considered non-specific, predominantly reflecting a changed vital state of the treated cells.

The direct effect of ultrasound is due to an immediate action of mechanical forces of the ultrasound field exerted on molecular and cellular structures. The influence of the temperature rise during sonication (by 1°C) was negligible and the incubation in the pure PBS was without effect on the cytoskeletal components studied. The depolymerization of cytoskeletal proteins is most probably due to shear forces damaging bonds in the cytoskeletal network. The effects of cytostatic drugs show some similarities to the indirect action of ultra-

sound that is mediated by chemically active substances, especially free radicals.

Conclusion

Ultrasound at low therapeutic intensities induced a partial disassembly of microtubules and microfilaments in HeLa cells due to depolymerization of essential proteins. The main mechanism seems to be the action of shear stress on cell structures. Similar changes in the cytoskeleton components were demonstrated after the application of two cytostatic drugs (cycloplatin and methotrexate). A combined action of ultrasound and cytostatics had a synergistic effect. In view of the fact that a physical and a chemical factor both had similar effects on the cytoskeletal system, the changes induced can be regarded as non-specific, reflecting only a changed vital state of treated cells.

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