In vitro percutaneous penetration of polycyclic aromatic hydrocarbons from sunscreen creams

Valentina Paolucci[1]
Roberta Liberatori[1]
Monica Pescaglini[2]
Pietro Sartorelli[1]

[1]Unit of Occupational Medicine, University of Siena, Italy
[2]Unit of Clinical Pathology Laboratory, Hospital of Siena, Siena, Italy

Corresponding Author:
Pietro Sartorelli
Unit of Occupational Medicine, Department of Medical Surgical and Neurological Sciences, University of Siena
Viale Bracci 16
53100 Siena, Italy
E-mail: pietro.sartorelli@unisi.it

Abstract

Background: **dermal exposure to Polycyclic Aromatic Hydrocarbons (PAHs) affects many outdoor workers such as asphalt workers. Usually the use of sunscreen creams is suggested to protect them from UV radiation. However sunscreens could prevent or facilitate dermal absorption of industrial chemicals. The aim of the study was to assess percutaneous penetration of anthracene using two different sunscreen creams as vehicle.**
Methods: in vitro **percutaneous penetration experiments were carried out using standardized *in vitro* methods with static diffusion cells. Excised human skin prepared to approximately 350 µm thickness was fixed on the diffusion cells. The receiving phase was a saline solution with 6% PEG 20. The two sunscreen creams (one lipophilic and the other idrophilic) were applied uniformly (2mg/cm^2) on the skin mounted on the diffusion cell. After 20 minutes a solution of anthracene and artificial sweat was added. Analysis of anthracene in the receptor samples was carried out by beta counter analyzer (Packard).**
Results: **in the receiving fluid both of cells where the lipophilic cream was applied and in those with idrophilic cream anthracene concentration was always below the detection limit.**
Discussion: **results did not show a percutaneous penetration of anthracene from sunscreen creams while in previous studies *in vitro* percutaneous penetration of anthracene was demonstrated using the same methodology in the absence of sunscreens. However the study was limited to a single polycyclic aromatic compound and two types of creams and this prevents to draw general conclusions. There is a need of experimental data on the influence of sunscreens on skin absorption of chemicals at workplace.**

KEY WORDS: anthracene, polycyclic aromatic hydrocarbons, sunscreens, skin absorption.

Background

Polycyclic Aromatic Hydrocarbons (PAHs) are known to be absorbed through the skin (1, 2). In a variety of workplaces percutaneous absorption of PAHs can result from direct skin contact or from deposition of airborne vapours and particles, representing an important route of uptake. Dermal exposure to PAHs affects also outdoor workers such as asphalt workers (3, 4). The International Agency for Research on Cancer (IARC) evaluated the occupational exposures during paving and roofing (in particular with coal-tar pitch) as carcinogenic to humans (5). This led over time to new approaches in assessing occupational exposure to PAHs among asphalt paving workers, founding that urinary metabolites of PAHs were associated with both inhalation and dermal exposure, though dermal exposure appeared to be the primary exposure route (6). A crossover study design was utilized to monitor a population of hot-mix asphalt paving workers under four exposure scenarios: (i) normal working conditions, (ii) increased dermal protection, (iii) increased inhalation protection, and (iv) substitution of biodiesel for the diesel oil often used by workers to clean tools and equipment (7). Results provided evidence of dermal absorption, suggesting also that PAHs in air were dermally absorbed. Promising strategies for reducing dermal exposure to PAHs among asphalt paving workers include requiring the use of dermal coverage (e.g. wearing gloves and/or long sleeves), substituting biodiesel for diesel oil as a cleaning agent, and decreasing the hot mix asphalt application temperature (8).
Usually the use of sunscreen creams is suggested to protect outdoor workers from UV radiation. In particular asphalt workers are also exposed to phototoxic effects of PAHs. However sunscreens could facilitate dermal absorption of chemicals. Brand et al. (9) tested *in vitro* percutaneous penetration of the herbicide 2,4-dichlorophenoxyacetic acid through the mouse skin

pretreated with different sunscreens. Of the nine sunscreens tested, six led to a significant enhancement of total 2,4-dichlorophenoxyacetic acid penetration as compared to the control ($p < 0.01$). Actually even an increased use of barrier creams seems to enhance the percutaneous uptake of chemicals such as aromatic amines (10).
The aim of the study was to assess percutaneous penetration of anthracene (a polycyclic compound very often present in PAHs mixtures) after the application of two different sunscreen creams with different physicochemical characteristic (one lipophilic and the other idrophilic).

Methods

In vitro percutaneous penetration experiments were carried out using standardized *in vitro* methods (11) with static diffusion cells (FDC 400, Crown Glass Co, NJ US) (Fig. 1).
The test apparatus was kept at a constant temperature of 37°C so that the skin surface temperature was 32°C. Static ambered cells with individual magnetic stirring and an exposure area of 1.77 cm^2 (diameter 1.5 cm) were used. Excised human skin (obtained from plastic surgery) prepared to approximately 350 µm thickness was fixed on the diffusion cells. Skin samples were frozen at -80° and stored for a maximum of 6 months. The receiving phase was a saline solution with 6% PEG-20 oleyl-ether. Lipophilic substances such as PAHs were previously found to diffuse well with this receptor (12). Yang et al. (13) using this type of experimental setting reported a similar percutaneous absorption of anthracene *in vivo* on the rat and *in vitro* through dermotomed rat skin with an *in vitro* penetration of 20% of the applied dose after 24 hours. The lipophilic and idrophilic sunscreen creams were applied uniformly (2 mg/cm^2) on the skin mounted on 24 and 32 diffusion cells respectively. After 20 minutes a solution of [^{14}C]anthracene (Sigma Aldrich) and artificial sweat was added. Nine 500 µl samples for each cell were drown every hour for 8 h and at 24 hours and replaced with receptor fluid. Analysis of [^{14}C]anthracene in the receptor samples was carried out by beta counter analyzer (Packard).
The experiment involved comparing the cumulative percutaneous penetration of anthracene in the different cells through a non parametric test (Mann-Whitney U test).

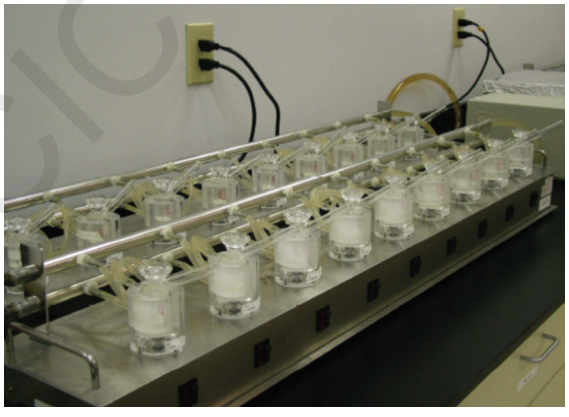

Figure 1 - The *in vitro* experimental setting with static diffusion cells.

Results

In the receiving fluid both of cells where the lipophilic cream was applied and in those with idrophilic cream anthracene concentration was always below the detection limit. For this the statistical comparison of the results was impossible.

Discussion

Results did not show a percutaneous penetration of anthracene after the application of sunscreen creams. Thus the use of sunscreen creams among outdoor workers would not seem to enhance percutaneous penetration of anthracene. Taking into consideration the results there is no basis for considering that sunscreens facilitate dermal absorption of PAHs. However the study was limited to a single polycyclic aromatic compound and two types of creams and this prevents to draw general conclusions. Actually there is a lack of knowledge on the influence of sunscreens and other types of creams (e.g. barrier creams) on skin absorption of chemicals at workplace. This represents a relevant issue when dermal exposure to these compounds can significantly contribute to the total systemic exposure. The occupational physician should take into account that a careful selection of sunscreen during outdoor work could reduce potential exposure to chemicals (9). The sunscreen creams used at workplaces where there is exposure to chemicals, in particular to carcinogens, should be tested as regards the possibility to act as enhancers. In this sense specific regulations are needed as is the case for gloves and other protective clothing.

References

1. Van Rooij JGM, Van Lieshout EMA, Bodelier-Bade MM, Jongeneelen FJ. Effect of the reduction of skin contamination on the internal dose of creosote workers exposed to polycyclic aromatic hydrocarbons. Scand J Work Environ Health. 1993; 19:200-207.
2. Moody RP, Nadeau B, Chu I. In vivo and in vitro dermal absorption of benzo(a)pyrene in rat, guinea pig, human and tissue-cultured skin. J Dermatol Sci. 1995; 9:48-58.
3. Fustinoni S, Campo L, Cirla PE, et al. Dermal exposure to polycyclic aromatic hydrocarbons in asphalt workers. Occup Environ Med. 2010; 67:456-463.
4. Sobus JR, McClean MD, Herrick RF, et al. Comparing urinary biomarkers of airborne and dermal exposure to polycyclic aromatic compounds in asphalt-exposed workers. Ann Occup Hyg. 2009; 53:561-571.
5. International Agency for Research on Cancer (IARC).

(2010). Some Non-heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposure. Available from: http://monographs.iarc.fr/ENG/Monographs/vol92/mono92.pdf
6. McClean MD, Rinehart RD, Ngo L, et al. Inhalation and dermal exposure among asphalt paving workers. Ann Occup Hyg. 2004; 48:663-671.
7. McClean MD, Osborn LV, Snawder JE, et al. Using urinary biomarkers of polycyclic aromatic compound exposure to guide exposure-reduction strategies among asphalt paving workers. Ann Occup Hyg 2012; 56:1013-1024.
8. Cavallari JM, Osborn LV, Snawder JE, et al. Predictors of dermal exposures to polycyclic aromatic compounds among hot-mix asphalt paving workers. Ann Occup Hyg. 2012; 56:125-137.
9. Brand RM, Spalding M, Mueller C. Sunscreens can increase dermal penetration of 2,4-dichlorophenoxyacetic acid. J Toxicol Clin Toxicol. 2002; 40:827-832.
10. Korinth G, Weiss T, Penkert S, et al. Percutaneous absorption of aromatic amines in rubber industry workers: impact of impaired skin and skin barrier creams. Occup Environ Med. 2007, 64:366-372.
11. Van de Sandt JJM, Van Burgsteden JA, Cage S, et al. In vitro predictions of skin absorption of caffeine, testosterone and benzoic acid: a multi-centre comparison study. Regul Toxicol Pharmacol. 2004; 39:271-281.
12. Bronaugh RL, Stewart RF. Methods for in vitro percutaneous absorption studies III: Hydrophobic compounds. J Pharm Sci. 1984; 73:1255-1258.
13. Yang JJ, Roy TA, Mackerer CR. Percutaneous absorption of anthracene in the rat: comparison of in vitro and in vitro. Toxicol Ind Health. 1986; 2:79-84.