Association Between Using Hair Dyes and Cancer Risk in a Population

Posted on February 19, 2024

Introduction

Hair dyes are used by millions of people, so even a small change in cancer risk would be important at the population level. The scientific question is difficult because “hair dye” is not one exposure. Products may be permanent, semi-permanent, or temporary; formulas have changed over time; darker permanent dyes generally use higher concentrations of some intermediates; and occupational exposure among hairdressers differs from occasional personal use. Cancer is also not one outcome. Studies have separately examined bladder cancer, breast cancer, non-Hodgkin lymphoma, leukemia, ovarian cancer, and other malignancies. (White et al., 2020)

The current evidence does not support the claim that hair dye protects users from cancer. Nor does it justify saying that all personal use causes cancer. The National Cancer Institute reports that findings for personal use are mixed and that the International Agency for Research on Cancer considers personal use of hair dyes “not classifiable as to its carcinogenicity to humans.” Occupational exposure is a separate concern because hairdressers and barbers may handle products repeatedly over many years. A well-designed population study should therefore measure type, color, frequency, duration, period of first use, application setting, and occupational exposure rather than dividing people only into “users” and “nonusers.” (International Agency for Research on Cancer, 2010)

What Existing Evidence Suggests

Concern about hair dye began partly because older permanent formulations contained aromatic amines that produced cancer in laboratory research. Manufacturers removed several of these chemicals in the mid- to late 1970s. This historical change matters: a person who began using permanent dye before 1980 may not have had the same exposure as a person using a modern product. Studies that combine all decades can obscure this difference.

Evidence for occupational exposure has been more concerning than evidence for personal use. IARC has classified occupational exposure as a hairdresser or barber as probably carcinogenic to humans, based largely on research involving bladder cancer and workplace exposures. Yet some recent-period studies have not observed the same risk, which may reflect reformulated products, improved ventilation, glove use, or other changes. Occupational status should therefore be measured directly rather than treated as equivalent to home use.

For personal users, results vary by cancer type and study design. Pooled analyses have generally not shown a clear overall association with bladder cancer. Research on non-Hodgkin lymphoma has produced conflicting findings, with some increased risks concentrated among people who used older formulations. Several large cohort studies have reported associations between certain permanent-dye exposures and breast cancer or selected other cancers, but effect sizes, subgroups, and findings have not been consistent across studies. An association in one subgroup does not prove that the product caused the outcome.

Research Question and Hypothesis

The proposed research question is: Among adults without a previous cancer diagnosis, is long-term use of permanent hair dye associated with the incidence of selected cancers compared with no personal hair-dye use?

A cautious hypothesis would be that frequent, long-duration use of permanent dye—particularly darker shades or products first used before major reformulation—may be associated with a small increase in the incidence of selected cancers. The study should not assume that the direction of the association is already known. It should be designed to detect increased risk, decreased risk, or no meaningful difference.

Recommended Study Design

A prospective cohort study is more ethical and informative than a randomized trial. Researchers should not deliberately assign healthy people to years of exposure that might increase cancer risk. Instead, they can enroll a large group of adults, document their existing hair-product practices, and follow them over time. Cancer outcomes can then be identified through medical records, pathology reports, and cancer registries.

The original proposal included 1,000 exposed and 1,000 unexposed participants followed for five years. That structure is understandable for a classroom design, but it is unlikely to provide enough statistical power for uncommon cancers. Many cancers have long latency periods, and five years may be too short to observe an effect that developed after decades of exposure. A stronger study would enroll tens of thousands of participants and use long-term follow-up, while the smaller 2,000-person design could be treated as a pilot focused on feasibility, exposure measurement, and short-term retention.

Defining the Exposure

Classifying exposure as “at least once a month for five years” loses important information. Researchers should record:

- whether the product is permanent, semi-permanent, temporary, a relaxer, or another chemical hair product;
- natural hair color and usual dye shade, because darker permanent colors may use different concentrations of intermediates;
- age at first use, calendar year at first use, total years of use, and applications per year;
- whether dye is self-applied, applied by another person at home, or applied by a professional;
- brand or ingredient information when participants can provide it;
- use of gloves, ventilation, scalp irritation, burns, or other indicators of contact;
- employment as a hairdresser, barber, cosmetologist, or salon worker.

Exposure should be updated during follow-up because people change products, stop dyeing, or begin using dye after enrollment. A one-time baseline question can misclassify participants and weaken the results.

Study Groups and Key Variables

Study Element	Exposed Group	Comparison Group
Participants	Adults aged 18–75 who report personal permanent hair-dye use	Adults aged 18–75 who report no personal hair-dye use at enrollment
Exposure detail	Frequency, duration, shade, product type, start year, and application setting	Continued nonuse verified during follow-up; new use recorded as a time-varying exposure
Primary outcomes	Incident bladder cancer, breast cancer, non-Hodgkin lymphoma, leukemia, ovarian cancer, and other prespecified cancers confirmed through registries or medical records	
Follow-up	Annual questionnaires plus long-term registry linkage, ideally for ten years or more	

Age and sex should not simply be listed; they should be incorporated into sampling and statistical analysis. Some cancers apply only to certain organs, and baseline risk changes substantially with age. Researchers should also ensure representation across racial and ethnic groups without treating race as a biological cause. Differences may reflect product patterns, hair practices, occupational exposure, access to care, socioeconomic conditions, discrimination, or other measured and unmeasured factors.

Confounding Variables

A confounder is associated with both the exposure and outcome and can create a misleading relationship. Important variables include age, sex, family history, tobacco use, alcohol consumption, body mass index, reproductive history, hormone use, occupational chemical exposure, ultraviolet exposure, socioeconomic status, healthcare access, and use of other hair products.

The original design proposed placing smokers in one group and never-smokers in the other. That would make the groups fundamentally incomparable. Smoking should instead be measured consistently in both groups—never, former, or current use, with duration and intensity where possible—and adjusted for analytically. The same principle applies to alcohol, diet, physical activity, and hormone therapy. Researchers should not define the exposed group by one risk pattern and the comparison group by another.

Restricting everyone to a body mass index below 28 would reduce generalizability and is not necessary unless the research question specifically concerns that population. It is usually better to measure BMI and related metabolic factors in both groups. “Environmental toxins” and “radiation” also require precise definitions. Occupational solvents, medical radiation, residential pollution, and ultraviolet radiation are different exposures and should not be collapsed into a vague category.

Bias and Data Quality

Recall bias may occur when participants cannot accurately remember products used years earlier. A prospective design reduces some recall problems because exposure is measured before cancer develops, but historical use still depends on memory. Photographs of packaging, product lists, salon records, and repeated questionnaires may improve accuracy.

Selection bias is another concern. People who volunteer for a study about hair products may differ from the wider population. Recruitment should use multiple settings and avoid enrolling only health-conscious volunteers or salon customers. Loss to follow-up must be monitored because participants who leave may differ in health, income, or exposure.

Detection bias can arise if dye users receive more medical screening than nonusers. Linkage to population registries helps, but researchers should still measure healthcare use. Outcome definitions must be established before analysis to reduce the temptation to highlight whichever cancer produces a statistically significant result.

Statistical Analysis

Incidence rates should be calculated for each prespecified cancer. Time-to-event models can estimate

hazard ratios while adjusting for confounders. Exposure may be analyzed as never use, former use, current use, cumulative applications, duration, and product type. Researchers should examine dose-response patterns rather than relying on a single yes-or-no comparison.

Subgroup analysis may be scientifically justified, but it increases the probability of chance findings. Analyses by sex, race and ethnicity, dye color, or start period should be prespecified and interpreted cautiously. Confidence intervals are more informative than a simple declaration that a result is "significant." Even a statistically detectable association may be small in absolute terms.

Why an Experimental Human Trial Is Inappropriate

The original essay suggested that a randomized controlled trial would be needed to demonstrate causation. Randomization is powerful, but it is not ethical or practical to assign participants to repeated potentially harmful chemical exposure for decades and wait for cancer. Causal inference can instead be strengthened through consistent cohort findings, exposure-response relationships, biological plausibility, careful adjustment, natural experiments involving reformulation, and triangulation with occupational and laboratory evidence.

Animal and mechanistic research can help identify hazards, but animal doses and routes of exposure may not match human use. No single study settles the question. Risk assessment combines evidence from multiple methods.

Ethics and Participant Communication

Participants should give informed consent for questionnaires, biological samples if collected, and registry linkage. Privacy protections are essential because medical and occupational data are sensitive. Researchers should not alarm participants by implying that hair dye is known to cause cancer, and they should not reassure them that it is proven safe. Recruitment materials should explain the uncertainty honestly.

Researchers can provide practical exposure-reduction information without overstating the evidence: follow product instructions, use gloves, avoid mixing products, ensure ventilation, do not use products on damaged skin, and seek medical advice for serious reactions. Salon workers may require stronger occupational protections because their cumulative exposure is higher.

Conclusion

The relationship between hair dyes and cancer risk cannot be answered by comparing a small group of "users" with a small group of "nonusers" while ignoring product type and historical formulation. Current evidence is mixed for personal use and more concerning for some occupational exposures.

Claims that hair dye reduces cancer risk are not justified by the overall evidence. (National Cancer Institute, 2022; Shah et al., 2020)

A credible prospective cohort would measure exposure in detail, follow a large and diverse population for many years, verify outcomes through registries, and adjust carefully for confounding factors. Its findings could identify particular products, time periods, or occupational patterns that deserve attention while avoiding the misleading conclusion that every dye and every user carry the same risk.

References

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