The High Price of Over-The-Counter Antiperspirants

Isabella High

Abstract: *The use of aluminum-based salts in antiperspirants is a topic of controversy in the science world. Despite the Food and Drug Administration (FDA) and European Union (EU) both approving topical use of several aluminum salts, modern research repeatedly demonstrates mutagenic effects of aluminum salts that could be accounting for the large surge in breast cancer over the past few decades. There is a gap in the research in which studies administering aluminum salts via ingestion are being used to approve the aluminum salts for topical use. Most research is not niche to topical application, and this composition intends to demonstrate the need for further research.*

Keywords: antiperspirants, aluminum salts, deodorant, breast cancer

Introduction

Aluminum-free deodorants have been used and marketed for decades due to aluminum allergies, but more recent information suggests that aluminum salts are largely unsafe for topical use, specifically at concentrations approved by the Food and Drug Administration (FDA). Antiperspirants are classified as drugs rather than cosmetics by the FDA because they modify the physiological function, sweating (CFR Title 21). For this reason, the FDA regulates what active ingredients can be used in antiperspirants and establishes what concentrations of the aluminum salts that are used as active ingredients in antiperspirants are regarded as generally safe and effective including "[a]luminum chloride up to 15%, calculated on the hexahydrate form, in an aqueous solution nonaerosol dosage form[… and] [a]luminum chlorohydrate up to 25[%]" (CFR Title 21). While the FDA approves the usage of these ingredients as long as they remain within the concentration limits, it is important to note that that these same ingredients are not recognized as safe and effective at concentrations exceeding the FDA's limits.

Knowing that these chemicals have the potential to be unsafe, it is critical for them to be highly regulated following thorough research. One concern among researchers in antiperspirant safety is that the research used to approve chemicals such as aluminum chloride and aluminum chlorohydrate is not specific enough to the biological setting in which these chemicals are being used. When conducting research, "aluminium needs to be tested in models more appropriate than conventional toxicological tests using rodents or bacteria because of well-known cell type and species-specific effects of cancer genes and carcinogens. Accordingly, current procedures of chemical testing and risk assessment have recently been questioned" (Belin et al. 234). Specifically, there is speculation that the aluminum salts being used in antiperspirants could be linked to breast cancer.

Aluminum Salts and Their Biological Risks

It has been proven that several aluminum salts can damage DNA, and there are strong correlations between the usage of antiperspirants containing aluminum salts and the development of breast cancer, especially in the outer region of the breast where antiperspirant is applied. Today, more than fifty percent of breast cancer tumors develop from the outer quadrant of the breast tissue (Darbre and Farasani 186). Genetic damage local to the areas of topical application can be noted and narrowed down to the mutated gene(s). For one, P.D. Darbre and A. Farasani from the School of Biological Sciences at Reading University wrote that "long-term exposure to Al [(aluminum)] causes a reduction in cellular levels of BRCA1 mRNA and BRCA1 protein in[…] human breast epithelial cells. Inheritance of loss of function of the BRCA1 gene, which encodes a protein involved in homology directed repair of DNA, is well established as a risk factor for susceptibility to breast cancer development" (Darbre and Farasani 188).

The Centers for Disease Control and Prevention (CDC) also stresses the link between mutations of specific genes and breast cancer development, as it affirms that mutations in the genes BRCA1 and BRCA2 increase a woman's chance of developing breast cancer. Interestingly, the CDC's website does not emphasize or mention avoiding potentially mutagenic chemicals as a strategy to prevent developing breast cancer. The risk factors for breast cancer that the CDC says individuals have control over are "[n]ot being physically active…[b]eing overweight or having obesity after menopause… [t]aking hormones… [r]eproductive history… [and drinking] alcohol (Centers for Disease Control and Prevention). While addressing these risk factors may help reduce the risk of developing breast cancer, this list excludes a factor that is critical to DNA health: the environment. Limiting exposure to mutagenic chemicals is important because environmental factors contribute to the risk of developing breast cancer. Genetic predispositions on their own only account for just under 10% of breast cancer developed (Darbre et al. 1485). It is time to question the safety of aluminum salts in antiperspirants, as the threshold for developing cancer is just one bad, unrepaired mutation.

Antiperspirants containing aluminum-based salts may increase the risk of breast cancer when used over time. Studies that have been used to approve the safety of aluminum salts in antiperspirants are not specific to topical application but rather ingestion and inhalation. A 1957 research composition Aluminum in the Environment of Man with over 1500 articles, reports, and books concluded that there was no risk with aluminum present in the "soil, atmosphere, vegetation…water, food, food processing, food containers, and medicines" (aluminum and deodorants 20). This research set the tone for aluminum's safety, despite it placing a large emphasis on ingestion when aluminum is not well absorbed by the gastrointestinal tract. For several following decades, there was no concern surrounding topical application because there had not been any reported evidence of dermal absorption, the absorption of a substance through the skin, taking place (aluminum and deodorants 20). The assumption that there was no issue with topical application of aluminum salts because there was no counterevidence pertaining to the safety was faulty, as it did not rule out the possibility that there could be a risk present. Now, much more is known about the dermal absorption of aluminum salts and its correlation with genetic mutations. This research compilation intends to demonstrate that the FDA's testing of aluminum salts is subpar by combining information from several different well-carried-out experiments as well as information the FDA itself publishes that together suggest that there is a risk to be addressed.

Societal Factors in Masking Scents

Standard western hygiene is not necessarily practical or correct. While in modern day body odor can be considered offensive, the current stigma around it is a cultural standard and fixation. Grooming is innate, but the concept of cleanliness took centuries to become what it is today. At the beginning of the 18th century in the Germanic world, bathing became understood as a contributing factor to one's health as medics began to recommend it. Over time, the concept of perceived cleanliness developed and became the primary concern of bathing (Ward 19), and from the second half of the 18th century on, bathing became increasingly popular across Western Europe as a tool to reinforce social hierarchy (Ward 24-25). Cleanliness demonstrated "good health, self-discipline, and personal responsibility" (Ward 24) and functioned to divide the rich from the poor as only the wealthy had access to public baths and personal bathrooms (Ward 24-25). This "clean" versus "dirty" narrative not only was applied to distinguish peasantry from working class and royalty, but it also increasingly catered to women, as the concept of femininity began to largely attribute cleanliness to purity (Ward 28).

With the weight that western society has put on cleanliness, people who either do not comply with or simply cannot match the standard of cleanliness are considered outcasts. Scent itself is a tool used to display conformity, as when someone is regarded as smelling bad, it means that they smell like themselves and their physiology (Brown 31). Someone who smells is not masking or removing this trait that is used to separate man from animal. Whether it is a choice or not, smelling bad is stigmatized. Psychotherapist Gabrielle Brown explains, "Strong personal odour provides a sense of an 'uncontained' state which brings with it a chilling reminder of the fragility of containing structures themselves" (Brown 31).

While body odor may be perceived as unpleasant and unhygienic, masking a scent or clogging sweat ducts to prevent perspiration is not true cleanliness either. Aluminum salts, most commonly aluminum chlorohydrate, are used as active ingredients in antiperspirants because they effectively precipitate in sweat ducts to form insoluble solids that act as physical barriers and plug the sweat ducts, blocking sweat (Deloncle et al. 148). Regardless, axillary scent will likely remain a significant concern for social acceptance despite its lacking influence on individual health. M. Kanlayavattanakul and N. Lourith write that "[h]eavy sweating or hyperhidrosis, particularly at axillary sites, leads to unpleasant odours that cause social embarrassment and reduce self-confidence, especially among women" (298). Not only is excessive sweating socially harmful, but it can also be difficult to control as it is very much a genetic trait as "sweat glands vary in density and size depending on race, sex, body site and determination techniques" (Kanlayavattanakul and Lourith 299).

Plugging sweat ducts is mere intentional dermal absorption, so the ingredients that go into antiperspirant products need to be safe and heavily regulated, otherwise these products can be potentially damaging to one's health. For example, a case in 2004 involved a woman who reported both bone pain and fatigue symptoms but had healthy test results when initially seeking medical care. When routine lab tests displayed normal results, mineral levels in blood were measured, and aluminum was present in the blood at 3.88 mol/L. These levels were abnormally high as a regular amount of aluminum is about 0.1–0.3 mol/L. The woman did report using an aluminum-based antiperspirant on shaved underarms daily for four years, accounting for approximately 157.3 g of aluminum-based salt. Other questioning revealed that she could not have been exposed to such a large amount of aluminum from her profession, medication use, ingestion, or use of utensils (Deloncle et al. 148). After having narrowed down the source of aluminum to antiperspirant application, the woman stopped applying antiperspirant entirely. After eight months of changing nothing in her lifestyle except for giving up her antiperspirant products, her aluminum levels had returned to a healthy, normal amount and her previous symptoms were entirely gone.

Additionally, it is important to note that the woman in the previously mentioned clinical case regularly shaved her underarms. Testing involving stick formulation antiperspirants, the most commonly used form of antiperspirant, has shown that shaved skin has micro-cuts and that may cause the absorption of aluminum through the skin and into the body to occur at a rate up to six times the normal rate of absorption. This observation suggests that skin with abrasions or damage to its natural barrier may be a significant pathway for aluminum to enter the bloodstream (Deloncle et al. 148).

Testing of Antiperspirant Aluminum Salts

In *The Journal of Inorganic Biochemistry*, researchers Darbre and Farasani report their studies on the safety of aluminum salts in antiperspirants. They suggest that aluminum salts in antiperspirants could be a cause of breast cancer due to the reported genomic instability as well as cancers of the outer quadrant of the breast correlating with the rise of antiperspirants over recent decades. Additionally, aluminum has been found in the tissue of human breasts as well as in breast cyst fluid and nipple aspirate fluid, suggesting that dermal absorption is taking place.

To develop an experiment, they used MCF10A human breast cells and cultured them in a control and in an experimental medium. The control cells were cultured in distilled water and the experimental cells were cultured in a solution containing aluminum chloride and aluminum chlorohydrate at concentrations 10-4 M. Both mediums contained the same amount of water (Darbre and Farasani 187). The cultures were treated for 19-21 weeks to assess the effects of long-term exposure.

To examine the effect the control and experimental solutions had on the cells' DNA, polymerase chain reaction was used to exponentially synthesize copies of DNA fragments that were then separated by gel electrophoresis. To examine gene expression, proteins were identified by immunoblotting. Darbre and Farasani concluded that the long-term exposure to aluminum chloride and aluminum chlorohydrate yielded reduced levels of BRCA1 mRNA as well as BRCA1 protein. They also observed a reduction of mRNA of other DNA repair genes including BRCA2, CHK1, CHK2, Rad51, and ATR (Darbre and Farasani 186). These changes demonstrate altered DNA expression, including that of DNA repair systems, suggesting that long-term exposure to aluminum salts may have a genotoxic and specifically carcinogenic effect.

The expression of the BRCA1 gene, a gene that serves an important role in decreasing breast cancer risk, changed in both experimental groups (aluminum chloride and aluminum chlorohydrate). For reference, control breast epithelial cells are the standard of functioning and so the control value is 1.0. Figure 2 above demonstrates how other relevant genes lost their ability to function when exposed to aluminum chloride and aluminum chlorohydrate.

Experiments displaying the mutagenic effects of topically applying aluminum salts are being reflected in the real world. Darbre has additional research published in *The Journal of Inorganic Biochemistry* with D. Pugazhendhi and F. Mannello on this topic. They note that breast cancer is novel in the sense that worldwide its current rates are unprecedentedly high, and that there is no certain explanation for what is driving this trend. One way to address this is to stop isolating breast cancer trends from those of other types of breast tumors because there are other types of breast tumors that have demonstrated similar trends in development and can potentially give insight as to why breast tumors are becoming increasingly common. Because of the high risks associated with breast cancer, it has maintained the highest profile of breast tumors. Other types of breast tumors are common, and include breast cysts and fibroadenomas, and these benign tumors as well as breast cancer disproportionately occur in the upper outer quadrant of the breast tissue where antiperspirant is applied (Darbre et al. 1484).

Some current regulations for aluminum-based antiperspirants include "[a]luminium chlorhydrate is limited to 25% w/v [(weight/volume)] by the Food and Drug Administration (FDA) of the USA and aluminium zirconium chloride hydroxide complexes are limited in cosmetics to 20% w/v by the FDA and in the European Union. Both the USA and EU include statements that these products should not be applied to broken, damaged or irritated skin" (Darbre et al. 1485). These standards are unrealistic and irresponsible to uphold. If products are only considered safe when applied in a small amount once daily and on perfect condition skin, then it is only fair to suggest that people who shave their underarms or apply antiperspirant multiple times in one day are at a greater risk of whatever negative consequences can come from these products. As mentioned previously, shaved underarms can absorb up to six times the amount of antiperspirant as unshaved underarms.

To further examine the genetic effects of exposure to commonly used aluminum salts, researchers performed a long-term study in which they observed the genetic profiles of cancerous human breast cells (MCF-7 cells) when cultured for 21 weeks with half of the cultures being treated with aluminum chlorohydrate. Experimental cultures were grown with a solution composing 10-4 M aluminum chlorohydrate, which had previously been reported as the highest possible concentration to not damage the growth of MFC-7 cells (Darbre et al. 1486). The data was translated into microarrays using the Amersham Codelink 20 K human expression microarrays and scanned with GenePix Array Scanner 4000B and then analyzed using GeneSpring technology. Results showed that the long-term exposure to aluminum chlorohydrate caused 50 genes to be upregulated by at least 200%, and 57 genes were downregulated by at least 100% (Darbre et al. 1486). While results displayed the mutagenic effects of aluminum, additional data demonstrated that observed levels of aluminum in the breast tissue are much higher than those in blood and breast milk, and that the distribution of aluminum within breast tissue is notably uneven and patchy (Darbre et al. 1487). This information suggests that breast tissue holds aluminum chlorohydrate well and can potentially become very saturated in patches, which could play into why aluminum chlorohydrate can be so mutagenic.

Additional Research

Researchers D. Belin et al., who have their work published in *The Journal of Applied Toxicology*, also have observed that the distribution of cancer has become increasingly uneven over time and favoring the outer region of the breast tissue. Hence, they argue "[a]lthough considered harmless by many, as with other putative carcinogens, aluminium needs to be tested in models more appropriate than conventional toxicological tests using rodents or bacteria because of well-known cell-type and species-specific effects of cancer genes and carcinogens. Accordingly, current procedures of chemical testing and risk assessment have recently been questioned" (Belin et al. 234). For these reasons, additional research had to be done.

MCF-10A mammary epithelial cells were purchased for further research. Aluminum chloride hexahydrate, an active form of aluminum chloride, was first dissolved in water at 1 M and then diluted to amounts 300, 100, or 10 mM, decreasing the relative concentration of the aqueous solution. "The stocks, or H2O as a control, were diluted 1:1000 in fresh culture medium twice a week for long-term culture, or for shorter treatments as indicated" (Belin et al. 234). Additionally, "the size of the colonies formed in soft agar by AlCl3-treated MCF-10A cells were consistent with [some of] the concentrations of aluminium used in experiments with antiperspirant" (Belin et al. 238).

It was not made clear how long cells were cultured for. There seemed to be a range from one to ten weeks. Nonetheless, it did yield measurable results by using polymerase chain reaction followed by gel electrophoresis. D. Belin et al. observed that aluminum chloride hexahydrate causes anchorage independent growth, breakage down the helix of double stranded

DNA, and biological aging. The report claims that this experiment demonstrated damage done to "epithelial cells at concentrations up to 100 000-fold lower than those commonly used in deodorants" (Belin et al. 242). Assuming measurements were made correctly during this experiment, this study suggests that current aluminum standards may not be rigorous enough because damage can be done when exposed to extremely small amounts of aluminum chloride hexahydrate.

P. Ferrari and S. J. Mandriota et al., have published their research in the *International Journal of Cancer*, note that although aluminum is thought to be safe and is used in a vast area of applications, very little is actually known about how aluminum interacts with biological systems. They decided to conduct an experiment using NMuMG murine mammary gland epithelial cells to examine the effects of aluminum exposure. Similar to the most previously mentioned experiment, aluminum chloride hexahydrate, the active form of aluminum chloride, was first dissolved in water at 1 M and then diluted to amounts 100, 30, and 10 mM, decreasing the concentration of the aqueous solution (Ferrari et al. 2782). Despite aluminum chloride hexahydrate having no initial consequence on the cells, between weeks 14 and 16 of the treatment, the experimental cells displayed irregular growth patterns and morphology, but the control cells displayed the regular "cobblestone-like" growth pattern (Ferarri et al. 2783). After viewing how aluminum chloride hexahydrate interrupted cell DNA function, it was time to bring lab animals into the picture to see how this chemical interacts on a larger scale.

Cells treated with aluminum chloride hexahydrate were injected into NSG mice, which have insufficient cytokine signaling and lack normal-functioning T cells, B cells, and natural killer cells. Due to their immunodeficiency, the mice's responses are largely due to the injected cells' material rather than their own immune systems attacking the foreign cells. Their responses were monitored for five weeks (Ferrari et al. 2783). Among the NSG mice, the control group was injected with cells that did not contain aluminum chloride. Both control and experimental groups developed tumors local to the sight of the cell injections, but the experimental group's tumors were much bigger. After six weeks, the mice were dissected. There was significant weight disparity between the mice injected with aluminum chloride and the control mice. Control mice had an average mass of 24.9 g with a standard deviation of 0.4 g, and experimental mice had an average mass of 20.6 g with a standard deviation of 1.3 g (Ferarri et al. 2783). Researchers found that "at the time of dissection, the lightest mouse injected with AlCl3-treated cells had massive, macroscopically visible metastasis in the lungs… [as well as] liver and brain metastasis… Of the four remaining mice injected with AlCl3 –treated NMuMG cells, all had massive metastasis in the lungs. These frequently presented with a central area of necrosis" (Ferarri et al. 2783).

Other Findings and Concerns

There are controversies in the beliefs towards the safety of aluminum. Some statistics prevent the puzzle from being completed. In 2002, a study found no correlation between aluminum-based antiperspirant use and breast cancer development when comparing 813 breast cancer patients to 793 people who had never developed breast cancer. (Deloncle et al. 148). Yet, a study the following year "reported with regard to a population of breast cancer patients that those who used more antiperspirant products on a shaved underarm tended to be diagnosed with breast cancer at an earlier age" (Deloncle et al. 148).

A potential problem in the overall research is that dermal absorption is not necessarily chemically the same as ingestion, yet ingestion methods have been used to test the cosmetic safety of aluminum salts. One concern, for example, is that "[t]here are [four] known polymorphs of crystalline aluminum hydroxide: gibbsite, bayerite, nordstrandite, and doyleite, which can have different properties. The properties of the environment (pH, presence of anions or salt and mineral surfaces) influence the formation of particular polymorphs" (Andersen et al. 17). Considering the factors that influence polymorphism, especially pH, it does not make sense to assume that the same aluminum hydroxide polymorph in an acidic stomach would be the same polymorph as topically applied aluminum hydroxide and vice versa. Polymorphism is already a large concern in pharmaceutical drug development, and the possibility that different polymorphs could be present between studies examining ingestion and topical application is worth examining.

With that being said, the FDA "concluded that the aluminum hydroxide used in cosmetics is chemically equivalent to that used in OTC antacid products. The FDA found that the information submitted for the approval of those drugs was adequate to support safe use" (Becker et al. 16). The FDA defines chemical equivalence as a "[s]ituation where the chemical characteristics of two materials or medical devices are sufficiently similar, such that the composition and processing do not result in additional or different toxicological concerns" (FDA Authority over Cosmetics). However, this conclusion is questionable as there is frequently a notable contrast between studies that examine ingestion versus topical application, and the FDA offers no explanation for the difference.

The difference in experimental results when testing aluminum hydroxide safety between ingestion and cosmetic application is drastic. When ingested, studies do suggest that aluminum hydroxide is safe. One study reported in the *International Journal of Toxicology* claimed "[t]here were no adverse effects observed when participants … were [orally] administered aluminum hydroxide … three times daily for six weeks" (Andersen et al. 24).

Another study used to test whether or not aluminum hydroxide raised any reproductive concerns involved female mice ingesting aluminum hydroxide. It was found that "[w]hen aluminum hydroxide…was administered by gavage on gestation days…[t]here were no differences in the number of total implants, resorptions, number of live or dead fetuses, fetal size parameters, or sex distribution observed at necropsy. There were no differences observed at gross external, soft tissue, and skeletal examinations" (Andersen et al. 24-25).

Conclusion

Despite all of the research that has been done, there are still gaps in the picture. For one, does the dermal absorption of the human breast epithelial cells used in these experiments accurately represent the average condition of human breast epithelial cells, many of which contain micro abrasions or sizeable cuts from shaving underarms? Also, sweat glands are porous and can increase dermal absorption. Any purchased culture of breast epithelial cells could easily not be from the porous underarm. Perhaps at the cellular level it doesn't make a difference, but it is something to consider. Lastly, studies repeatedly use ingestion methods to test the safety of topical aluminum hydroxide. This could be dangerous because different polymorphs could exist between the skin and the digestive tract due to significant variance in pH and yield different properties that may cause different effects on the body. This could be the reason why studies show such different results between ingestion and topical application and why the FDA's position on several aluminum salts is controversial.

Future experiments should address these gaps in the research. The usage of ingestion to test topical safety has created a loophole in which chemicals are being regarded as safe in multiple conditions when they have only been evaluated in one. Topical application should be used more in studies that address the safety of topical use. Cell cultures with micro abrasions should be used in experiments to represent the condition of day-to-day human breast epithelial cells more accurately. Finally, it should be noted what polymorphs are present/formed in studies that involve aluminum hydroxide because this can play a role in experimental results.

Most research on the topical application of aluminum salts used in antiperspirants suggests that several aluminum salts are genotoxic and could be causing breast cancer over time. Combined with the unprecedented high rates of breast cancer, there is an evident need for change. Too often, lab results from experiments involving the ingestion of aluminum-based chemicals are used when evaluating the safety of cosmetic, topically applied products. More niche research that compares topical application to ingestion must be done to understand the safety of aluminum-based salts in antiperspirants and the disparity in the research.

It is critical to educate adolescents about environmental factors that may contribute to breast cancer development because choices adolescents make involving chemical exposure affect the likelihood of developing breast cancer as an adult. Part of this is because breast development occurs in adolescence, making it a particularly vulnerable time. For this reason, "[s]tructures present in the mammary gland of pubertal girls and rodents are highly sensitive to environmental insults[...]. Prior studies have demonstrated an increased risk for breast cancer in girls exposed to radiation or environmental chemicals during adolescence compared to women exposed later in life" (Jerry et al. 1).

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