Mobile Phones: Potential Sources of Nickel and Cobalt Exposure for Metal Allergic Patients

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The use of cellular phones has risen exponentially with over 300 million subscribers. Nickel has been detected in cell phones and reports of contact dermatitis attributable to metals are present in the literature. We determined nickel and cobalt content in popular cell phones in the United States. Adults (>18 years) who owned a flip phone, Blackberry®, or iPhone® were eligible. Seventy-two cell phones were tested using SmartPractice's® commercially available nickel and cobalt spot tests. Test areas included buttons, keypad, speakers, camera, and metal panels. Of the 72 cell phones tested, no iPhones or Droids® tested positive for nickel or cobalt. About 29.4% of Blackberrys [95% confidence interval (CI), 13%–53%] tested positive for nickel; none were positive for cobalt. About 90.5% of flip phones (95% CI, 70%–99%) tested positive for nickel and 52.4% of flip phones (95% CI, 32%–72%) tested positive for cobalt. Our study indicates that nickel and cobalt are present in popular cell phones. Patients with known nickel or cobalt allergy may consider their cellular phones as a potential source of exposure. Further studies are needed to examine whether there is a direct association with metal content in cell phones and the manifestation of metal allergy.

Introduction

THE USE OF CELLULAR PHONES has risen exponentially over the last 10 years, accounting for an estimated 178 billion dollars spent annually on cell phone services and over 875 billed minutes per month in the United States in 2010.^{1,2} In addition to talking on the phone, national surveys reveal that people use cell phones for a wide range of activities, including texting, emailing, web browsing, game playing, and listening to music.³ The Cellular Telecommunications Industry Association (CTIA) reported that Americans sent and received 565 messages per month in 2010, a fourfold increase from 2007.² The National Health Interview Survey from the CDC reported that 3 out of every 10 American homes use a mobile phone as their primary phone.⁴

A European group sought to determine the amount of nickel released from popular cell phones. They reported that 8 out of 41 cell phones (19.5%) tested positive for dimethylglyoxime (DMG), indicating that the item released >0.5 µg nickel/cm²/week.⁵ The European Union (EU) Nickel Directive,⁶ which was instated in 1994 to reduce nickel release from consumer items, was revised in 2009 to include nickel-releasing cell phones.^{7,8}

Nickel is the most common allergen found among patch-tested patients.^{9–12} In a recent follow up to the Odense Adolescence Cohort Study,¹³ 11.4% of respondents reported that they had eczematous dermatitis to metal contact (buttons,

buckles, jewelry). After the implementation of nickel regulation in the EU, nickel sensitization was significantly less among younger age groups, particularly in women.^{14–17} In contrast to the findings in Europe, the prevalence of nickel allergy has increased steadily among all age groups in the United States.¹¹ A recent epidemiologic study of nickel allergy in America and China¹⁸ found a significant increase in the prevalence of nickel allergy in the U.S. since 1970; a significant increase in the prevalence of nickel allergy in China was also seen.¹⁸ The development of dermatitis by means of nickel sensitization occurs through prolonged cutaneous exposure from items such as jewelry, tools, coins, watches, and belt buckles.⁵ The European Commission proposed prolonged contact as greater than 30 min of continuous or more than 1 h total of discontinuous skin contact in a day.¹⁹ It has been reported that individuals spend ~50 min a day using cell phones in the United States.²⁰

The clinical relevance of metal content in cell phones leading to contact dermatitis has been suggested by several case reports (Tables 1 and 2), with 24 cases attributable to nickel allergy and the remainder secondary to chromates.^{5,21–37} The majority of these cases were characterized by pruritic, eczematous papules and plaques on the lateral cheeks and/or preauricular area. The dermatitis typically presented unilaterally and in an irregular shape.²¹ However, other less common sites included the thighs (from cell phones kept in pant pockets) and in one case between the breasts (this was

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TABLE 1. REPORTED CASES OF CELL PHONE CONTACT DERMATITIS DUE TO NICKEL

Report date	Age/sex	Country	Patch test results	DMG testing of phone	Dermatitis improved with reduced contact? ^a	Ref.
2000	36 F	Italy	Nickel positive	Not stated	Yes	30
	32 F		2+ Nickel	Positive	Yes	
2007	25 F	France	2+ Nickel	Positive	Unknown	25
2007	19 F	Austria	3+ Nickel	Positive	Unknown	37
2008	18 M	USA	Nickel positive	Positive (headset)	Yes	26
2008	32 M	India	2+ Nickel	Not performed	Yes	27
2008	28 F	Denmark	Nickel positive	Positive	Unknown	5
2009	15 F	USA	2+ Nickel	Positive	Yes	28
	13 F		1+ Nickel	Positive	Yes	
	18 F		2+ Nickel	Positive	Yes	
2009	25 F	France	3+ Nickel, 2+ cobalt 1+ palladium	Positive	Yes	23
2010	3 Pts	Korea	Nickel and cobalt positive in all three patients	Not stated if performed	Unknown	24
2010	39 M	Australia	Nickel positive	Positive	Yes	32
2010	38 M	Italy	3+ Nickel	Positive	Yes	22
2010	28 F	USA	Not stated	Not stated	Yes	31
2011	12 M	USA	All with prior history of nickel sensitivity	All positive	Yes (patient 1)	21
	17 F		Except patient 4		Unknown	
	16 F				Unknown	
	18 M				Unknown	
	14 F				Unknown	
2011	33 M	Turkey	Not performed	Positive	Yes	29
2011	14 F	USA	Nickel positive	Positive	Unknown	35

DMG, dimethylglyoxime; Pts, patients; M, male; F, female.

where the patient housed her phone); a high index of suspicion is needed particularly in these less prevalent locations.^{22,35}

In cases where DMG testing was performed on the suspected cell phone, all results were positive. Discontinuing use of the cell phone led to resolution of the dermatitis.^{23,26,28,32} In reports where the phone was not discontinued, the use of plastic films, casings, and belt pouches also led to an improvement of the dermatitis.^{22,29,30} One study testing 22 cell phones and a Bluetooth headset found that the most common cell phone sites that contain free nickel are menu buttons, metal frames around the LCD display, and decorative logos on the headset. This group suggested that covering these areas may help to prevent or improve cell phone contact dermatitis in nickel-allergic patients.²⁶

Cobalt coexists with nickel in nature and is often seen as an impurity in nickel-containing products.¹⁶ The prevalence of cobalt allergy is estimated to be in 1% of the general population.³⁸ Historically, isolated cobalt allergy is seen in metal workers, brick layers, and pottery workers through occupational exposure.³⁹ However, a study conducted in the United States from 2001 to 2004 revealed that 12% of children with dermatitis had a relevant cobalt allergy.⁴⁰ Although a decrease in nickel sensitization was seen after the implementation of regulations in Europe, the prevalence of cobalt allergy remained the same.^{14–17,39,41} A study performed in Denmark to determine whether cobalt had replaced nickel in jewelry after the implementation of the EU Nickel Directive showed that cobalt was detected in only 1.1% of the items.⁴² Another study looked at the cobalt

TABLE 2. REPORTED CASES OF CELL PHONE CONTACT DERMATITIS DUE TO CHROMATES

Report date	Age/sex	Country	Patch test results	Improvement of dermatitis after reducing contact?	Ref.
2002	35 F	Japan	2+ Potassium dichromate	Yes	34
2003	54 M	Japan	All positive to potassium dichromate;	All improved	33
	32 F		Pt 3 also 1+ nickel and Pt 2		
	27 F		also 1+ cobalt		
	19 M				
	25 F				
	18 M				
	14 M				
	35 F				
2011	71 M	Australia	1+ Potassium dichromate	Yes	36

TABLE 3. TOP SELLING MOBILE PHONES IN THE UNITED STATES 2011⁴³

Total mobile by brand	Smart phone by brand	Top selling models January–December 2011
Samsung [®] (25.3%)	Apple [®] (29.6%)	(1) Apple iPhone4 [®]
LG [®] (20%)	RIM [®] (16%)	(2) Apple iPhone3Gs [®]
Motorola [®] (13.3)	HTC [®] (14.6%)	(3) Apple iPhone 4S [®]
		(4) RIM-Blackberry Curve 8530 [®]
		(5) HTC-EVO 4G [®]

release from cell phones. Of the randomly selected sample of 50 new mobile phones for sale, no cobalt release was detected.³⁹ Interestingly, there have been four cases of patients with cell phone dermatitis deemed to have both nickel and cobalt sensitivity on patch testing, whose dermatitis improved with reduced cellular phone contact, however, the cellular phones were not tested for cobalt.^{23,24}

Given the rise in nickel and cobalt sensitization and reports of cell phone dermatitis in the literature, our aim was to investigate whether nickel or cobalt was present in top selling cellular phone models in the United States.

Methods

Phone selection

Phones from top selling models determined by comScore MobiLens⁴³ data were selected for our study (Table 3). Wherever possible, multiple phones of the same model were included for testing. Table 4 contains a complete list of cellular phones tested in this study.

Patient selection

Adults over the age of 18 who owned one of the listed phones were invited to contribute one or more phones for testing. IRB approval was obtained from the Winthrop University Hospital with oral informed consent from each participant.

Phone testing

Phones were tested using SmartPractice's[®] Reveal and Conceal Nickel and Cobalt Spot Test Kits. A total of five areas per phone were tested, including the camera, keypad, metal logo, side panels, and speakers. All areas tested were recorded and are reported. Each area was swabbed first with the nickel cotton-tipped plastic applicator for 30–60 seconds, and a positive test was determined by a change in the applicator tip from white to light pink or strawberry red (Fig. 1). A reaction was reported as negative if no color change was observed. A known nickel containing coin was used as a positive control, and a non-nickel containing plastic case served as a negative control. The nickel spot test was followed by the cobalt spot test performed at a different site. The reagent for nickel was DMG, and the reagent for cobalt was 1-nitroso naphthol 3,6 disulfonic acid disodium salt. The cobalt spot test becomes positive when cobalt is released at ~8 ppm.⁴⁴ To minimize the risk of false positives, after testing with one reagent, the phone was wiped down with a dry cloth and tested with the second reagent. For each spot test, different areas of the cell phones were tested. All positive tests were confirmed and repeated on separate days.

Literature review

A search for peer reviewed literature using the PubMed search engine was performed using the following keywords:

TABLE 4. RESULTS OF NICKEL AND COBALT RELEASE FROM MOBILE PHONES

Brand	Type of phone	Model	No. of phones tested	No. of (%) phones nickel positive	No. of nickel-positive areas ^a	No. of (%) phones cobalt positive	No. of cobalt-positive areas ^a
Apple	Smartphone	iPhone 3GS	3	0		0	
	Smartphone	iPhone 4	12	0		0	
	Smartphone	iPhone 4S	10	0		0	
RIM (Blackberry)	Smartphone	Bold 9650	8	4 (50%)	4 (Keypad)	0	
	Smartphone	Torch 9860	1	0		0	
	Smartphone	Curve 8530	4	0		0	
	Smartphone	Tour 9630	4	1 (25%)	1 (Keypad)	0	
Motorola	Smartphone	Droid 2 A955	9	0		0	
	Flip phone	v265	2	2 (100%)	2 (Middle button)	0	
	Flip phone	E815	1	1 (100%)	1 (Middle button)	1 (100%)	1 (Middle button)
	Flip phone	v950	2	0		0	
LG	Flip phone	VX4400	7	7 (100%)	7 (Middle button); 7 (back of phone); 2 (side button)	2 (28.6%)	2 (Middle button); 2 (side button)
	Flip phone	CV500	1	1 (100%)	1 (Middle button, ear speaker)	1 (100%)	1 (Middle button)
Samsung	Flip phone	VX6100	1	1 (100%)	1 (Middle button)	0	
	Flip phone	SCHA670	6	6 (100%)	6 (Middle button); 3 (side button); 3 (back of phone)	6 (100%)	6 (Middle button)
Sony Ericsson [®]	Flip phone	Z520a	1	1 (100%)	1 (Middle button)	0	

^aA single phone may have tested positive in more than one area. Positive results are in bold.

FIG. 1. Positive Nickel (top) and Cobalt (bottom) spot tests.

cell phone, mobile phone, dermatitis, allergic contact dermatitis, cell phone allergy, nickel and cobalt dermatitis, and consumer item allergy. Studies and case reports discussing dermatitis due to cell phones and attributable to metal allergy were included for review.

Results

A total of 72 cell phones from seven different manufacturers were tested. We found that 24 of 72 cell phones [33%; 95% confidence interval (CI), 24%–45%] tested positive to nickel using DMG. Ten out of 72 phones (14%; 95% CI, 8%–24%) tested positive for cobalt, all of which were flip phone middle buttons. In addition, two of seven side buttons were positive for cobalt in the LG VX400® model. All of the Samsung SCH670® models (6/6) were cobalt positive.

Of the 24 phones with nickel positivity, 20.8% were Blackberrys® and 79.2% were flip phones. Of the five Blackberrys that tested positive, four were model Bold 9650 (four of eight tested positive for nickel) and one was model Curve 9630 (one of four phones tested positive for nickel). In the flip phone category, 90.5% of phones tested positive for nickel (95% CI, 70%–99%), with the middle button and back of the phone the most common sites of nickel release. Only one flip phone tested negative for nickel, the Motorola v950®, a rubber-coated sports model. Of the 25 iPhones® and 9 Motorola Droid A955® models tested, none were positive for nickel or cobalt. Table 4 contains a complete list of phone results.

Discussion

Previous studies performed in Europe demonstrated nickel positivity in 18%–26% of mobile phones tested, with rates of nickel sensitivity higher in conventional or nonsmart phones (Table 5).^{5,45–48} One study in the United States in 2008 found that 10 of 22 (45%) mobile phones tested positive for nickel.²⁶ Our results are similar in that conventional cell phones (nonsmart phones) tested positive for nickel, with nickel positivity in our study higher than that detected in Europe, but lower than the previous study conducted in the United States.

Our study indicates that nickel and cobalt are present in popular cell phones, particularly flip phones. This is the first study to demonstrate cobalt positivity in cellular phones. About a third of Blackberrys tested, but no iPhones or Droids tested, had detectable nickel or cobalt. Although none of the 25 iPhones we tested were found to release either nickel or

TABLE 5. STUDIES INVESTIGATING NICKEL AND COBALT RELEASE FROM CELL PHONES

Report date	Country	Metal tested	+ Nickel or cobalt identified	Ref.
2008	Denmark	Nickel	8/41 (19.5%)	5
2008	USA	Nickel	10/22 (45.5%)	26
2009	Denmark	Nickel	1/27 (3.7%)	47
2009	Denmark	Nickel	5/20 (25%)	48
2010	Denmark	Nickel	8/26 (30.7%)	45
2011	Denmark	Nickel	9/50 (18%)	46
2012	Denmark	Cobalt	0/50 (0%)	39

+, positive.

cobalt by means of the spot test in our study, there is a report of an iPhone 5® model testing positive to nickel through DMG testing⁴⁹ and Apple MacBook Pro laptops^{50,51} testing positive to nickel using DMG in the literature.

It is important to note, however, that we did not correlate a patient's clinical history with cell phone type or the development of dermatitis. Evaluation of cell phones in patients with known nickel or cobalt allergic contact dermatitis would better demonstrate whether phone use correlates directly with contact allergy or sensitization.

Nickel positivity was found in phones with keypads, while none of the touch screen models were positive. Interestingly, the Blackberry models that tested positive for nickel had significant wear on the keypad (Fig. 2). We suspect that the surface coating may initially prevent the release of nickel from keypads, but wear may lead to nickel exposure. Another hypothesis is that consumer products that release nickel may do so due to treatment with nickel coating substances as was recently found on a laptop computer⁵⁰ that released between 0.2 and 0.3 µg nickel/cm² of nickel per week depending on the area tested (bottom surface, hand rest).

The cellular phone models tested in our study differ from those previously evaluated. Additionally, our study was unique in that wherever possible, multiple phones of the same make were tested. Despite this, there was still variability among phones of the same model. This may be due to

FIG. 2. Worn Keypad on Blackberry Model 9650®.

the use of different suppliers for cell phone parts based on the price and availability.⁵ Thus, the finding of nickel in a small number of phone models cannot be extrapolated to the millions of phones found worldwide.

Although this study is the largest to date, testing more phones of the same model would allow a better understanding of the degree of variability within a single cell phone model. Assessing the same phone after time has elapsed may provide insight into our theory regarding age or wear of the phone contributing to a positive test.

No cell phone accessories were tested in our study. Future investigations on metal release from phone accessories, such as cases, adaptors, and headsets, may identify additional sources of metal exposure. Additionally, other known contact allergens such as rubber, acrylates, and polyurethane components of mobile phones also warrant investigation.

The hallmark of treatment for allergic contact dermatitis is avoidance. Patients with known nickel or cobalt allergy should consider their cellular phones as a potential source of exposure. This is particularly important as more and more people are using their cell phones as their primary phones and laptops/tablets as their primary computers, which result in a greater amount of skin exposure to nickel and other metals. This change is occurring not only during personal time, but also during educational activities as tablets and computers are being utilized as teaching tools.⁵² It is essential that the public is aware that sensitization can occur through exposure and that commonly used everyday products contain nickel. Legislation to control nickel release in the United States may help decrease the prevalence of nickel allergy as it has done in Europe.

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Author Disclosure Statement

All the authors declare that they have no conflict of interests.

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