In-Flight Ultraviolet Radiation on Commercial Airplanes

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INTRODUCTION: Epidemiological studies suggest that pilots and cabin crew have higher incidences and mortality rates of cutaneous malignant melanoma than those of the general population. Exposure to UV radiation is one of the main risk factors for this type of cancer. The aim of this study was to evaluate the level of UV radiation in an airliner in flight.

METHODS: Measurements were taken with a three sensor-integrated electronics UV radiometer (A, B, and C) during 14 flights from July to October 2016. They were performed during daylight hours once the airliner had reached cruising altitude.

RESULTS: We failed to find UVC radiation. The measurements detected neither UV A nor B in any parts of the cabins of the planes tested, nor in the Airbus cockpits. UVA radiation was however found in the cockpit of Boeing 777s. But UVA levels remained well below the values found at ground level and they were also strongly reduced (more than 10 times) by cockpit sun visors.

DISCUSSION: Few studies have assessed the level of UV radiation in an airplane. They suggested that the cockpit windshields reduced this type of radiation to some degree (according mainly to the wavelength of the radiation and the nature of the windshield). Our study strongly confirms these results and suggests that increased incidence of melanoma and mortality by this type of illness found among pilots and airline cabin crews may not be related to in-flight UV radiation exposure.

KEYWORDS: cutaneous malignant melanoma, pilots and cabin crew, ultraviolet radiation.

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The results of a meta-analysis involving nineteen articles published between 1990 and 2013, with 266,431 participants, mention a significant increase in cutaneous malignant melanoma incidence and mortality among the airline companies' crewmembers, with no significant difference between pilots and flight attendants. This study does not clarify the reasons for the findings, but the authors emphasize the potential role of UV radiation to which crewmembers could be exposed during their flights, on the assumption that this type of radiation is proved to be a factor of melanoma and that the level of UV radiation increases with altitude.

This hypothesis remains to be demonstrated. Firstly, because the pilots' and flight attendants' work conditions are not identical, but more importantly because the aircraft fuselage and cockpit's windshields have the capacity to filter or block UV radiation.

The aim of this study was to measure the level of UV radiation in the different parts of an aircraft in flight, in order to estimate the importance of this occupational exposure and thus to assess its potential impact on the incidence (and mortality rate) of melanomas among airline pilots and cabin crew.

METHODS

Measurements were taken from July 6 to October 23, 2016 on several models of the following airplanes used by a major European airline for medium and long range flights: Airbus A319, A330, A380, and Boeing 777. The flights were selected to take into account the variability of radiation levels linked to longitude

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and latitude. The measurements were taken during daylight hours and started as soon as the plane was stabilized at cruise altitude (from 30 to 39,000 ft, more than 10,000 m altitude).

Several sets of measurements were taken for each flight (three to seven sets depending on the flight duration). The study was designed to give the UV radiation level (A, B, and C) at four points of measurement in the cockpit (at the level of the left elbow and right eye of the pilot sitting on the left side, and the right elbow and left eye for the pilot sitting on the right side) and at several points of measurements in the aircraft galleys (the number of galleys varying from one in the Airbus A319 to five in the Airbus A380). A set of measurements (of UV A, B, and C radiation) was taken in the pilot and cabin crew rest compartments during each flight. Random measurements were taken at the windows of the aircraft doors.

Additional measurements (UV A and B) were taken on four Airbus models (A320, A330, A340, and A380), at Paris Charles de Gaulle airport on September 13, 2016 between 12:25 and 13:50 (UTC, clear sky with few high clouds), in order to complete the data collected during the flights.

All these measurements were carried out with a Radiometer RM12 manufactured by OPSYTEC, equipped with 3 UV sensors: A (315 to 380 nm), B (280 to 315 nm), and C (200 to 280 nm). This device instantaneously measures UV radiation levels, expressed in milliwatts per centimeter squared, with a resolution degree of 0.01 $mW \cdot cm^{-2}$. For the measurements in the cockpit, the sensor was orientated toward a window and stabilized in the position where the radiation level was the highest. For the measurements in the cabin (galleys and rest compartments) the sensor was orientated in different directions and in different places in order to detect any possible radiation. The measurements taken at the aircraft doors were taken with the sensor close to the windows.

RESULTS

There were 1197 points of measurement taken during 14 flights: 4 on Airbus (A319, A330 and A380) and 10 on Boeing 777. The 10 Boeing flights allowed us to cover an area ranging from 1°01 south to 69°40 north and from 138° east to 119°32 west (**Table I**). Almost all of the measurements were performed with clear sky and no clouds.

UVC radiation was not discovered in any part of all these aircrafts.

Neither UVB nor A radiation were found in the galleys, in the crew rest compartments or close to aircraft doors' windows.

No UV radiation (A or B) was detected in any of the Airbus' cockpits during the flights. The measurements taken at Paris CDG airport, on September 13 (**Table II**), confirmed this constatation when the cockpit windows were closed. But when one of the windows was open, there was naturally some UV radiation (measurements ranged from 0.92 up to 1.25 $mW \cdot cm^{-2}$ for UVA and 0.29 up to 0.35 $mW \cdot cm^{-2}$ for UVB). Measurements taken on the taxiway during this period found levels of radiation ranging from 2.4 up to 2.8 $mW \cdot cm^{-2}$ for UVA and 0.80 to 0.89 $mW \cdot cm^{-2}$ for UVB.

On the other hand, some UVA radiation and a low amount of UVB were detected in the Boeing 777 cockpits (**Table III**).

Of the 180 in-flight measurements taken with a UVA sensor in the Boeing cockpits, 11 were taken through a sun visor placed on the windshield and 4 seemed abnormally low (probably due to the use of a B or C sensor). The average level of UVA radiation for the 165 consistent measurements taken without sun visors was 0.34 $mW \cdot cm^{-2}$ (values ranged from 0.01 to 1.22 $mW \cdot cm^{-2}$). When measurements were recorded through a sun visor, the UVA radiation levels did not exceed 0.12 $mW \cdot cm^{-2}$ and were at least 10 times lower than measurements taken at the same points without sun visors.

The measurements were taken with the B sensor in an identical manner to those executed with the UVA sensor (170 times without a sun visor and 10 times with a sun visor) in Boeing 777 cockpits.

The levels found never exceeded 0.13 $mW \cdot cm^{-2}$ and most of the time were close to zero (mean level 0.01 $mW \cdot cm^{-2}$) for the 170 measurements taken without sun visors.

DISCUSSION

Several epidemiological studies have confirmed an increase of the incidence and/or mortality caused by cutaneous malignant

Table I. Summary of Airline Flights.

DATE	AIRCRAFT TYPES	DESTINATIONS *	CRUISING ALTITUDE (ft) **	LATITUDE	LONGITUDE
6 July	Airbus A319	Casablanca (D/R)	37 to 39,000	37°00′N - 46°19′N	0° 00′ - 5°48′W
7 July	Boeing 777-300	Beirut (D/R)	36 to 37,000	34°51′N - 47°52′N	7°30′E - 34°32′E
2 Sept.	Airbus A330	CDG - Delhi	32 to 39,000	41°36′N - 48°23′N	05°08′E - 47°70′E
9 Sept.	Boeing 777-200	CDG - Vancouver	36 to 38,000	51°41′N - 69°40′N	1°42′W - 119°32′W
11 Sept.	Boeing 777-200	Vancouver - CDG	33,000	49°47′N	117°48′W
18 Sept.	Airbus A380	CDG - Abidjan	37 to 38,000	13°53′N - 39°10′N	2°41′E - 0°02′W
19 Sept.	Boeing 777-300	CDG - Tokyo	33 to 39,000	39°N - 62°N	4°E - 138°E
22 Sept.	Boeing 777-300	Tokyo - CDG	32 to 37,000	43°N - 69°N	8°E - 136°E
8 Oct.	Boeing 777-200	CDG - Panama	34 to 39,000	18°00′N - 48°36′N	2°56′W - 75°00′W
9 Oct.	Boeing 777-200	CDG - Panama	37,000	47°30′N - 49°30′N	17°30′W - 35°42′W
21 Oct.	Boeing 777-300	CDG - Lima	30 to 36,000	46°53′N - 1°01′S	5°36′W - 71°43′W
24 Oct.	Boeing 777-300	Lima - CDG	33 to 36,000	27°45 N - 36°31 N	33°19′W à 13°42′W
	All flights		30 to 39,000	1°01 S - 69°40 N	119°32′W - 138°E

* All flights departed from or had returned to Paris CDG airport; ** cruising altitude in feet.

Table II. UV Radiation Levels (in mW · cm^{-2}) on the Taxiway and in Four Airbus' Cockpits on the Ground.

	UV LEVELS / AIRBUS AIRLINERS	A 380	A 330	A 340	A 320
UVA	On the taxiway	2.60	2.46	2.46	2.75
	In the cockpit with all windows closed	0.00	0.00	0.00	0.00
	In the cockpit with the left window open	1.25	0.92	0.95	0.92
UVB	On the taxiway	0.80	0.89	0.89	0.85
	In the cockpit with all windows closed	0.00	0.00	0.00	0.00
	In the cockpit with the left window open	0.30	0.29	0.35	0.33
		12h25*	12h45*	13h00*	13h50*

* Measurement time (UTC) on the 13th of September at Paris CDG Airport.

melanoma among pilots and cabin crew.[5,10,15] The meta-analysis performed by Martina Sanlorenzo's team,[15] with nearly 300,000 participants, found an overall standardized incidence ratio (SIR) of melanoma at 2.21 (95% CI, 1.76–2.77) and a general standardized mortality ratio (SMR) of 1.42 (95% CI, 1.27–2.63). The incidence ratios were very similar between pilots and flight attendants, since the SIR of pilots was 2.22 and SIR of cabin crew was 2.09.

Three environmental factors attached to this type of professional activity are commonly cited to explain these results: exposure to ionizing cosmic radiation, circadian rhythm disturbances, and exposure to UV radiation during flights.

However, it is doubtful that cosmic ionizing radiation is responsible for the increased incidence of melanoma among aircrew members since a link between ionizing radiation (whether cosmic, telluric, or artificial) and melanoma has never been formally demonstrated.[6] In 2013, a Finnish cross-sectional survey[11] confirmed this finding for a female cabin crew population. And the follow-up of the airline pilots and cabin crews of our company (more than 16,000 people) in 2015 shows that the average annual rate of ionizing radiation was 2.20 mSv and that the highest value did not exceed 4.84 mSv.

Flight crew activity causes regular and significant circadian rhythm disruptions (especially for long-haul flights). But although night work has been linked with several types of cancer, it is not the case for melanoma.

On the other hand, there is a recognized link between melanoma and sun exposure[1,8,15] or artificial ultraviolet radiation.[1,12,18] We also know that UV radiation level increases by 10 to 12% for each kilometer in altitude,[2,17] which means that UV radiation levels could be at least two or three times higher at the usual cruising altitude for commercial aircraft (above 10,000 m) than at sea level. However, the expected increase of UV radiation levels inside an airplane, because of flight altitude, should be offset by the filtration capacity of the aircrafts' fuselage and cockpit windshields.

Few studies until now had investigated the capacity of airplanes' windshields to filter UV radiation and results vary. The first study,[4] carried out in 1990, was performed with UV dosimeters worn by airline pilots on 18 flights (flight time less than or equal to 6 h) and concluded that there was no significant presence of UV radiation in Boeing 737 or 767 cockpits. However, it should be noted that the sensitivity of the dosimeters used for this study (wavelength less than 320 nm) did not take into account UVA radiation.

A second study[13] was performed in 2006 by the Civil Aerospace Medical Institute of the Federal Aviation Administration with measurements taken on disassembled windshields from three jet airliners (MD88, A320, and Boeing 727/737), two turboprop airliners (ATR42 and Fokker27), one private jet, and two single-engine propeller general aviation planes. The results showed that there was no transmittance (or less than 1%) of UVB for the windshields of all these planes, and no transmittance of UVA for the polycarbonate windshields (found on single-engine propeller planes). However, the airliners' laminated glass windshields allowed a certain quantity of UVA radiation to pass through (the percentage could reach 53.5%, depending on the radiation wavelength and/or the type of airplane).

In 2015, Sanlorenzo and coworkers carried out a study[16] to compare the radiation level present in the cockpit of a small turboprop business airplane (Socata TBM850, equipped with an acrylic windshield and able to fly to 30,000 ft) to the levels in a tanning bed. This study was done with two radiometers (Solartech UV index meter): one covering the UV A and B range, the other one limited to UVB measurements. Levels of UVA radiation in the airplane's cockpit did not exceed 0.25 mW · cm^{-2} at an altitude of 25,000 ft (compared to 0.137 mW · cm^{-2} in this airplane on ground) during two flights carried out in April in California and Nevada. They found no UVB radiation.

Table III. Flight UV Radiation Levels (in mW · cm^{-2}) in Boeing 777 Cockpits.

	UVA			UVB		
FLIGHTS / UV	NUMBER OF MEASURES	MEAN LEVEL	HIGHEST VALUE	NUMBER OF MEASURES	MEAN LEVEL	HIGHEST VALUE
Beirut A/R	24	0.30	1.12	24	0.02	0.09
CDG - Vancouver	17	0.14	0.21	17	0.00	0.01
Vancouver - CDG	4	0.12	0.16	4	0,00	0.00
CDG - Tokyo	12	0.25	1.12	16	0.00	0.00
Tokyo - CDG	25	0.42	1.01	25	0.02	0.13
CDG - Panama	24	0.39	0.80	24	0.01	0.05
Panama - CDG	8	0.24	0.80	8	0.01	0.04
CDG - Lima	27	0.45	1.20	28	0.04	0.09
Lima - CDG	24	0.41	1.22	24	0.02	0.12
All flights	165	0.34	1.22	170	0.01	0.13

All these measurements were performed without sun visors.

The last study[3] was published in 2016. It aimed to compare the impact of UV radiation on the eyesight of airliner and helicopter pilots to that of office employees. The measurements were taken with a radiometer (Ocean Optics HR4000) during five medium-haul flights, one transatlantic flight and four helicopter flights (from off-shore platforms). The unit of measurement chosen (the Ocular UVA dose rate, in $j \cdot m^{-2}$) prevents a direct comparison with our results. But this publication confirmed the absence of significant UVB radiation and found a considerable variation in the levels of UVA radiation. For the authors, this was above all related to the uneven quality of the windscreens.

The results of these five studies suggest that the increased incidence of melanomas for cabin crew and airline' pilots is not related to UV radiation during a flight. Other factors, be they behavioral or intrinsic, may explain the increased incidence of melanoma in pilots and cabin crews. In several publications, there has been an increase in short, intense and repeated exposures to UV radiation (natural or otherwise) for this type of occupational population compared to the general population.

An Icelandic case control study[14] published in 2003, which compared melanoma risk factors between airline crewmembers (pilots and female cabin attendants) and the general population did not show any significant difference between these two groups. However, it did show several significant differences concerning aircrew. These include having more than 100 nevi, a greater number of severe sunburns after 19 yr and much greater sun exposure in particular.

A prospective study[5] published in the United Kingdom in 2012 took data from 1989 to 2008 to compare the incidence of cancers between airline pilots and air traffic control officers, taking into account different risk factors, professional and personal (innate or behavioral). It found an increase in the rate of melanoma for these two groups compared to the general population. The authors suggested that non-work-related factors may have influenced this situation, especially the greater frequency of brief but intensive periods of sun exposure.

A Finnish cross-sectional survey carried out in 2013 by Kojo[11] of female cabin crewmembers versus the general population did not show any significant differences between these two groups regarding the risk factors usually associated with skin cancers, apart from a temporary level of exposure to the sun as well as a significantly higher use of solariums for cabin crew.

A selection bias could also be considered for this type of population, such as phenotypic factors,[1,9,14] high number of nevi,[1,7,14] family history of melanoma.[1,9,14]

CONCLUSION

Using a radiometer equipped with three types of different sensors (UV A, B, and C), over 1000 measurements were taken from July to October 2016 during 14 medium and long-haul flights and over an extended geographical area (more than half the Earth's surface) to estimate the UV radiation level in an airliner once stabilized at cruise altitude.

This study showed that no UVC radiation was found in flight, in any part of the airliners tested. It also confirmed that no UV A or B radiation was present in the cabin of the tested airplanes. The measurements taken in the cockpit gave discordant results, depending on the type of airplane tested. No UV radiation (A, B or C) could be detected in the cockpit of Airbus aircraft. No UVC radiation and very little UVB was present in cockpits of the Boeing 777, although some UVA radiation was. The UVA levels measured in these cockpits were, however, much lower than those found at ground level (**Table IV**) and were very strongly attenuated by the installation of the sunshades.

The results of our study make it possible to formally eliminate a link between UV radiation in flight and increased incidence of melanomas for flight attendants. They suggest also, as those of the four studies which evaluated UV radiation level in a cockpit, that the increased incidence of cutaneous malignant melanoma for pilots appears not to be due to exposure to UV radiation in flight.

Further research into other occupational (or personal) factors that could account for the excessive prevalence of melanomas for airline crews seems necessary. It may also be useful to make aeronautical manufacturers aware of the merits of having cockpit windshields that sufficiently filter all UV radiation for the lifespan of their airplanes. But, it seems also very important to make pilots and flight attendants aware of the consequences of excessive exposure to UV radiation, whether natural or artificial, outside of flying.

Table IV. Ground UV Radiation Values (in $mW \cdot cm^{-2}$) During the Study.

DATE	TIME (UTC)	PLACE OF MEASUREMENT	GPS LOCALIZATION	WEATHER	UVA	UVB
7 July	5h30	Paris CDG Airport	49°00′N, 2°34′E	sunny	0.45	0.07
7 July	12h10	Beirut Airport	33°82′N, 35°48′E	sunny	3.38	1.05
2 Sept.	7h05	Paris CDG Airport	49°00′N, 2°34′E	sunny	1.10	0.21
13 Sept.	13h50	Paris CDG Airport	49°00′N, 2°34′E	sunny	2.75	0.89
18 Sept.	6h35	Gournay sur Marne	48°86′N, 2°58′E	cloudy	0.31	0.10
18 Sept.	8h20	Paris CDG Airport	49°00′N, 2°34′E	lightly cloudy	1.10	0.21
9 Oct.	15h00	Panama	9°00′N, 80°00′W	sunny	2.48	0.80
21 Oct.	10h00	Paris CDG Airport	49°00′N, 2°34′E	very cloudy	0.49	0.13
22 Oct.	11h00	Lima	11°80′S, 76°90′W	hazy	1.21	0.53

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