ORIGINAL REPORT

Knowledge Gaps on Skin Cancer and Sun Protection in Organ Transplant Recipients Under Long-term Immunosuppression

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Organ transplant recipients (OTRs) face an elevated risk of skin cancer due to ultraviolet radiation (UVR) exposure and the need for chronic immunosuppression. Patient education is essential for early skin cancer detection and prevention. This cross-sectional study evaluated knowledge and attitudes regarding sun protection and skin cancer among 177 OTRs during their routine check-up at a specialized dermatologic outpatient clinic in a German University Hospital, using the validated Skin Cancer and Sun Knowledge (SCSK) scale. Demographic, clinical and transplant-related variables were analysed to identify factors associated with specific knowledge gaps. The mean SCSK score was 16.59 (standard deviation, SD±3.96). While most patients understood basic sun protection, key deficits were noted in their understanding of tanning risks, the meaning of sun protection factor (SPF) and symptoms of skin cancer. Heart transplant recipients (p=0.002) and those with immunosuppression >3 years (p=0.028) had significantly lower scores indicating inferior knowledge. Male sex and age <40 and >60 years were also associated with lower knowledge levels. Self-reported "well-informed" patients scored significantly higher (p=0.003). Despite specialized routine dermatologic care, knowledge gaps persist in high-risk subgroups of OTRs, highlighting the need for targeted, longitudinal education strategies in interdisciplinary transplant aftercare.

Key words: Organ transplant recipients; Skin cancer risk; Sun protection knowledge; Immunosuppression; Patient education.

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SIGNIFICANCE

Organ transplant recipients are at higher risk of skin cancer due to immunosuppressive medication and sun exposure. This study evaluated how well 177 transplant patients understood sun safety and skin cancer. While many were aware of basic sun protection, substantial proportions did not fully understand important details like tanning dangers, correct sunscreen use and cancer signs. Certain groups – including heart transplant patients, those on medication for over 3 years, men and younger or older adults – knew less. Even with regular skin check-ups, knowledge gaps remain. This shows the need for ongoing, targeted education to enhance skin cancer prevention in transplant recipients.

Long-term iatrogenic immunosuppression is associated with a markedly increased risk of cutaneous malignancies, particularly keratinocyte cancers (KCs) such as squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) (1–3). Among solid organ transplant recipients (OTRs), the risk of SCC may be up to 65-fold higher than in the general population which has been primarily attributed to two major contributing factors: long-term immunosuppressive therapy and cumulative ultraviolet radiation (UVR) exposure (1–4). The clinical management of KC in OTR is complicated by the typically elevated cumulative number of lesions with subsequent tumours, particularly SCC, arising at an accelerated rate in chronically UVR-exposed sites of the skin (2, 3, 5). In the general population, the prognosis of most KCs is favourable when detected early and treated appropriately. Yet, OTRs exhibit significantly poorer outcomes – particularly for SCC – due to an increased risk of loco-regional recurrence and metastatic spread associated with chronic immunosuppression (1, 2, 6), an independent risk factor for disease-specific death from SCC (1, 7, 8).

Despite UVR being the most important modifiable risk factor for KC, skin cancer awareness and compliance with strict photoprotection (including sunscreen, appropriate clothing and behavioural measures), as generally recommended for immunosuppressed patients (1, 4, 6), remain inadequate in this high-risk patient group (9–13). Previous research suggests that knowledge of skin cancer may be positively associated with sun-protective behaviour (14, 15). In agreement with other international guidelines (1), the German guideline on skin cancer prevention states that "knowledge about an increased risk of skin

cancer and the implementation of protective behaviours needs to be improved in organ transplant recipients".

To better understand these challenges and address knowledge gaps tailored to the specific needs of high-risk populations, validated assessment tools are essential. The Skin Cancer and Sun Knowledge (SCSK) scale, a questionnaire-based instrument, has been designed to evaluate knowledge regarding sun protection and skin cancer and has been increasingly applied in both general and high-risk populations to guide personalized intervention (16, 17). Recently, a German-language version of the SCSK scale has been developed and psychometrically validated (16, 18), now enabling its application for standardized knowledge assessment in German-speaking clinical and research settings. Hypothesizing that long-term immunosuppressed OTRs exhibit knowledge gaps regarding skin cancer and sun protection, this study aims to systematically assess level of knowledge using the validated SCSK scale, to identify key knowledge deficits and associated transplant- and non-transplant-related variables among long-term immunosuppressed OTRs in Germany and to contribute to the development of targeted educational strategies.

METHODS

Study design

This monocentric cross-sectional study, titled *SCSK-IS (Skin Cancer and Sun Protection Knowledge – Immunosuppression*) was conducted between August 2023 and August 2024 at the Department of Dermatology, University Hospital Heidelberg, Germany, and its Skin Cancer Center at the National Center for Tumor Diseases, Heidelberg. Participation was voluntary, and all participants gave written informed consent after receiving verbal and written information on the study's purpose, procedures, benefits and risks. To avoid any influence from subsequent medical consultation, participants completed the paper questionnaire in advance in the clinic waiting room, which required approximately 10–15 min. The study followed the Declaration of Helsinki and was registered in the German Clinical Trials Registry (DRKS00032511, 17 August 2023) after ethics approval from the Ethics Committee of the Medical Faculty Heidelberg (approval number S-440/2023, 16 August 2023).

Participants

Participants were regularly cared for at the Department of Dermatology's specialized outpatient clinic for chronically immunosuppressed patients and underwent full-body skin examinations at least once a year as part of a risk-adapted aftercare regimen proposed by Ulrich et al. (19). Consecutive patients were recruited during routine clinical visits. Inclusion criteria included: age ≥18 years, solid organ transplantation, use of immunosuppressive therapy for ≥1 year, legal capacity and the ability to complete the questionnaire without assistance.

Variables and measurements

Skin cancer and sun protection knowledge levels, the primary outcome of the study, were assessed using the recently validated German version (18) of SCSK scale (20). The SCSK scale, developed and validated to measure skin cancer and sun protection knowledge, has shown satisfactory psychometric properties in diverse immunocompetent and immunosuppressed populations (16, 18, 20, 21), with internal consistency (KR-20) between 0.51 and 0.69, and test–retest reliability from r=0.52 to r=0.83 (p<0.001) (22). The SCSK questionnaire includes 25 items across 5 domains: risk factors, prevalence, symptoms, sun protection and tanning behaviour. The first 15 items are true/false; the remaining 10 are single-answer multiple choice questions. The total SCSK score ranges from 0 to 25, with higher values reflecting better knowledge. Subscale scores were analysed as secondary outcomes. Three additional questions were added: 2 on the relevance of immunosuppression for skin cancer risk and need for sun protection, and 1 assessing participants' perceived information sufficiency. Demographic and clinical data (e.g. age, sex, smoking status, personal/family skin cancer history, screening frequency, Fitzpatrick skin type, transplanted organ and immunosuppression duration) were recorded by the treating physician.

Statistical analysis

Analyses were conducted using IBM SPSS Statistics, version 29.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were applied for all variables. The SCSK total and subscale scores were described and analysed at item level. Additional questions were analysed using means±SD or absolute frequencies. Associations between participant characteristics and knowledge scores were assessed using Mann–Whitney U and Kruskal–Wallis tests. A p-value<0.05 was considered statistically significant.

RESULTS

Participant characteristics

Questionnaires of 177 OTRs (62.1% male) with a mean age of 56.91 years (SD±15.79; range 18–88) and mostly Fitzpatrick skin type II or III (81.9%) were analysed:

48.0% of OTRs reported a personal and 14.1% a family history of skin cancer. Most participants were non-smokers (91.5%) and underwent regular, at least annual, skin cancer screenings (89.8%). Kidney transplantation was most common (58.8%) and 70.1% of OTRs had been under immunosuppressive therapy for ≥10 years. Missing data were limited to a few variables: smoking status was missing in 6 cases, family history of skin cancer in 16 cases and Fitzpatrick skin type in 13 cases (**Table I**).

Total SCSK score and subscale analysis

The mean total SCSK score in the total cohort was 16.59 (SD±3.96; range 1–24). Only 7.3% of participants (n=13) scored ≤10 points, while 26.6% (n=47) scored between 11 and 15 points, 50.8% (n=90) between 16 and 20 and 15.3% (n=27) above 20 points.

The distribution of SCSK scores across the 5 specific SCSK subscales (sun protection, tanning, risk factors, prevention, symptoms) according to the classification by Day et al. (20) is provided in **Table II**. Subscale analyses revealed mean scores of 8.04 (SD±2.20) for items related to knowledge of sun protection, 8.42 (SD±2.03) for tanning, 2.88 (SD±0.97) for skin cancer risk factors, 1.16 (SD±0.57) for skin cancer prevention and 0.44 (SD±0.50) for skin cancer symptoms (Table II).

Knowledge deficits in specific questionnaire items

A complete overview of the individual questionnaire items along with a breakdown of correct item responses and categorization by specific subscales is provided in the supplementary material (Table SI). Only 24.3% of OTRs correctly identified tanning as a sign of skin damage. BCC was recognized as the most common skin cancer by only 28.2%, and only 17.5% understood the correct meaning of sun protection factor (SPF) 30. In response to the two supplementary items on the relevance of iatrogenic immunosuppression, 98.9% of OTRs acknowledged the elevated skin cancer risk due to chronic immunosuppression, and 97.2% affirmed the importance of sun protection measures for immunosuppressed patients (Table SII) . Most OTRs (73.4%) felt adequately informed about sun protection and skin cancer (Table SIII) .

Transplant-related and non-transplant-related variables affecting skin cancer and sun protection knowledge

Statistical analysis revealed significant differences in total SCSK scores according to transplanted organ (p=0.023) with the lowest mean score of 14.21, SD±4.43 reached by heart transplant recipients. Duration of immunosuppression was also significantly associated with knowledge (p=0.005), with the lowest scores observed among patients with 10–20 years of immunosuppressive therapy (mean 15.68, SD±3.91), and highest among those with <3 years (mean 19.38, SD±2.39). Overall, heart transplantation (p=0.002) and duration of immunosuppression >3 years (p=0.028) were significantly associated with lower knowledge scores.

Significant associations were found for age (p=0.045) and sex (p=0.040) with lower knowledge scores among male OTRs and those <40 or >60 years. Other non-transplantation related variables (smoking status, history of skin cancer, screening frequency, Fitzpatrick skin type) were not significantly associated with SCSK

Table I. Demographic and clinical characteristics of the study cohort (n=177)

	All participants (n=177)
Age overall in years, mean (SD)	56.91 (15.79)
(Min–Max: 18–88)	
<40 years, n (%)	27 (15.3)
40–49 years, n (%)	15 (8.5)
50–59 years, n (%)	50 (28.2)
>60 years, n (%)	85 (48.0)
Sex	
Female, n (%)	67 (37.9)
Male, n (%)	110 (62.1)
Smoking	
Yes, n (%)	9 (5.1)
No, n (%)	162 (91.5)
Missing, n (%)	6 (3.4)
Personal history of skin cancer (invasive and pre-invasive)	
Yes, n (%)	85 (48.0)
No, n (%)	92 (52.0)
Family history of skin cancer	
Yes, n (%)	*25 (14.1)*
No, n (%)	*136 (76.8)*
Missing, n (%)	*16 (9.0)*
Regular skin cancer screenings	
Never, n (%)	7 (4.0)
Every 2 years, n (%)	9 (5.1)
1 x per year, n (%)	86 (48.6)
2 x per year, n (%)	37 (20.9)
>2 x per year, n (%)	36 (20.3)
Missing, n (%)	2 (1.1)
Skin type according to Fitzpatrick[a)]	
I, n (%)	9 (5.1)
II, n (%)	57 (32.2)
III, n (%)	88 (49.7)
IV-VI, n (%)	10 (5.6)
Missing, n (%)	13 (7.3)
Type of organ transplant	
Kidney, n (%)	104 (58.8)
Liver, n (%)	30 (16.9)
Heart, n (%)	24 (13.6)
Lung, n (%)	7 (4.0)
Multiple organs[b)], n (%)	12 (6.8)
Duration of immunosuppression in years, mean (SD)	14.71 (8.78)
(Min–Max: 1–45)	
<3 years, n (%)	8 (4.5)
3–10 years, n (%)	45 (25.4)
10–20 years, n (%)	78 (44.1)
>20 years, n (%)	46 (26.0)

a) Ref.: Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol. 1988 Jun;124 (6):869–71. doi: 10.1001/archderm.124.6.869. PMID: 3377516; b) Kidney and pancreas (n=4), kidney and liver (n=3), kidney and heart (n=2), kidney and lung (n=1), kidney, lung and heart (n=1), lung and liver (n=1)
SD:standard deviation.

Table II. Mean total SCSK and subscale scores

Total points (25 items), mean (SD) (Min–Max: 1–24)	16.59 (3.96)	
Sun protection (12 items), mean (SD) (Min–Max: 1–12)	8.04 (2.20)	
Tanning (11 items), mean (SD) (Min–Max: 0–11)	8.42 (2.03)	
Skin cancer risk factors (4 items), mean (SD) (Min–Max: 0–4)	2.88 (0.97)	
Skin cancer prevention (2 items), mean (SD) (Min–Max: 0–2)	1.16 (0.57)	
Symptoms of skin cancer (1 item), mean (SD) (Min–Max: 0–1)	0.44 (0.50)	

Note: The number of items indicates how many questions are assigned to this (sub)scale. Min–Max describes the range achieved by our cohort.
SD:standard deviation.

scores. However, a non-significant trend suggested a positive correlation between screening frequency and knowledge level (mean score of 14.29, SD±4.31 in unscreened vs 17.11, SD±3.62 in those screened more than twice annually) (**Table III**).

Lastly, patients self-assessed information level correlated significantly with knowledge levels measured by the SCSK scale (p=0.003): those who felt well-informed had a higher mean score (17.06, SD±3.60) than those who did not (mean 13.67, SD±3.93) (**Table IV**). Subscale analysis (Tables III and IV) revealed a significant correlation of patients self-assessed information level with SCSK scores in the areas of sun protection (p=0.009), tanning (p=0.010) and skin cancer risk factors (p=0.018). Further, significant differences were found for age in relation to knowledge of risk factors for skin cancer (p=0.010) and for sex with regard to sun protection knowledge (p=0.050). A family history of skin cancer was significantly associated with the "tanning" subscale (p=0.010), as was the type of organ transplant (p=0.034). Duration of immunosuppression was significantly associated with knowledge in the areas of sun protection (p=0.029), tanning (p=0.007), and skin cancer prevention (p=0.047). **Fig. 1**. illustrates transplant-related and non-transplant related variables associated with reduced skin cancer and sun protection knowledge overall.

DISCUSSION

In chronic immunosuppressed OTRs, KCs represent a significant and growing burden of disease, and health education and the implementation of photoprotective strategies are generally recommended to reduce the impact of post-transplant skin cancer in this high-risk population (1, 2, 4, 6). This study evaluated skin cancer and sun protection knowledge among OTRs using the recently validated German version of the SCSK scale. The findings reveal an overall moderate level of knowledge, with pronounced deficits in specific domains, such as the recognition of skin cancer symptoms, interpretation of SPF and the harmful nature of tanning among certain patient subgroups in the post-transplantation period.

The mean total SCSK score of 16.59 out of 25 (SD±3.96) among OTRs in our study is comparable to the mean SCSK score reached by a German cohort of non-immunosuppressed university students (15.64, SD±3.16) (18). Only a few studies previously evaluated sun protection and skin cancer knowledge in OTRs using the SCSK scale as a standardized, validated tool. In a small cohort of 25 Australian renal transplant recipients, Thet et al. evaluated the effectiveness of an integrated skin cancer programme with a reported mean SCSK score of 19.7 (SD±3.1) prior to education (17). In Turkish cohorts, markedly lower mean SCSK scores were reported for both, OTRs (10.98, SD±4.64 (10); 12.17, SD±2.84 (23)) and immunocompetent patients (14.21, SD±3.00 (10)) (13.34, SD±0.22 (24)). Cultural and ethnic background may influence the participants' level of knowledge regarding skin cancer and sun protection, underlining the importance of using a questionnaire that has been validated across different languages to ensure accurate and culturally sensitive assessment.

Subscale analyses suggested that knowledge was relatively stronger regarding sun protection practices but notably poorer in identifying skin cancer symptoms and understanding risk factors in our cohort. The importance of patient education targeting symptom recognition has been emphasized in previous research, as early diagnosis improves outcomes in immunosuppressed patients with KCs (6). Although encouragingly high awareness was found for the relationship between immunosuppression and skin cancer risk (98.9%), detailed item analysis revealed critical knowledge gaps in our cohort: only 24.3% recognized tanning as a sign of skin damage, and a mere 17.5% correctly understood the meaning of SPF 30 – results that mirror prior findings from both general population studies and immunocompromised cohorts (25, 26). These deficits are clinically relevant as tanning is often misperceived as harmless or even beneficial, potentially leading to risky UVR exposure (25). Consistent with prior studies, these results suggest that although OTR may be aware of basic protective behaviours such as sunscreen use and clothing coverage, deeper conceptual understanding is lacking (11, 27).

Accounting for more than 80% of KCs in the general population, BCC is the overall most common type of skin cancer (28). Yet, in chronic immunosuppressed populations, SCC occurs with significantly higher incidence than BCC compared with the general population, resulting in a typical inversion of SCC:BCC

Table III. Variables affecting the skin cancer and sun knowledge scale and subscale scores

		SCSK subscale scores				
	SCSK score	Sun protection	Tanning	Skin cancer Risk factors	Skin cancer prevention	Symptoms of skin cancer
Age, mean (SD)	***p=0.045****	*p=0.078*	*p=0.452*	***p=0.010****	*p=0.250*	*p=0.226*
<40 years	15.11 (5.15)	7.11 (2.95)	7.89 (2.55)	2.93 (0.87)	1.19 (0.48)	0.26 (0.45)
40–49 years	17.53 (3.52)	8.73 (1.98)	8.40 (1.88)	3.33 (1.11)	1.13 (0.52)	0.40 (0.51)
50–59 years	17.62 (3.52)	8.58 (1.88)	8.74 (1.93)	3.10 (0.76)	1.30 (0.51)	0.46 (0.50)
>60 years	16.28 (3.72)	7.89 (2.04)	8.41 (1.94)	2.66 (1.03)	1.07 (0.63)	0.48 (0.50)
Sex, mean (SD)	***p=0.040****	***p=0.050****	*p=0.139*	*p=0.054*	*p=0.153*	*p=0.109*
Female	17.15 (4.15)	8.39 (2.22)	8.67 (2.04)	3.01 (1.04)	1.24 (0.55)	0.36 (0.48)
Male	16.25 (3.83)	7.83 (2.17)	8.27 (2.02)	2.80 (0.92)	1.11 (0.58)	0.48 (0.50)
Smoking, mean (SD)	*p=0.288*	*p=0.168*	*p=0.409*	*p=0.216*	*p=0.777*	*p=0.180*
Yes	15.11 (4.17)	7.22 (1.86)	7.78 (2.54)	2.56 (0.88)	1.11 (0.60)	0.22 (0.44)
No	16.70 (3.95)	8.07 (2.21)	8.48 (2.03)	2.91 (0.97)	1.17 (0.57)	0.45 (0.50)
Personal history of skin cancer, mean (SD)	*p=0.289*	*p=0.340*	*p=0.454*	*p=0.278*	*p=0.635*	*p=0.068*
Yes	17.00 (3.56)	8.26 (2.00)	8.60 (1.81)	2.81 (0.96)	1.18 (0.60)	0.51 (0.50)
No	16.21 (4.29)	7.84 (2.36)	8.26 (2.22)	2.95 (0.98)	1.14 (0.55)	0.37 (0.49)
Family history of skin cancer, mean (SD)	*p=0.060*	*p=0.065*	***p=0.010****	*p=0.567*	*p=0.651*	*p=0.573*
Yes	18.12 (3.02)	8.84 (1.52)	9.36 (1.32)	2.96 (0.94)	1.12 (0.53)	0.48 (0.51)
No	16.18 (4.11)	7.79 (2.27)	8.22 (2.16)	2.84 (0.97)	1.17 (0.60)	0.42 (0.50)
Regular skin cancer screenings, mean (SD)	*p=0.237*	*p=0.405*	*p=0.088*	*p=0.074*	*p=0.673*	*p=0.373*
Never	14.29 (4.31)	6.86 (2.67)	6.71 (2.22)	3.00 (0.82)	1.43 (0.54)	0.43 (0.54)
Every 2 years	14.56 (4.33)	7.22 (2.73)	7.67 (2.29)	2.44 (1.24)	1.22 (0.44)	0.11 (0.33)
1× per year	16.74 (4.25)	8.01 (2.25)	8.50 (2.13)	3.05 (1.01)	1.12 (0.56)	0.44 (0.50)
2× per year	16.41 (3.62)	7.97 (1.99)	8.32 (2.06)	2.76 (0.83)	1.14 (0.59)	0.49 (0.51)
>2× per year	17.11 (3.62)	8.44 (1.99)	8.81 (2.06)	2.67 (0.83)	1.19 (0.59)	0.44 (0.51)
Skin type according to Fitzpatrick[a], mean (SD)	*p=0.780*	*p=0.768*	*p=0.709*	*p=0.052*	*p=0.502*	*p=0.995*
I	16.78 (2.64)	8.33 (1.50)	8.89 (1.54)	2.11 (0.93)	1.22 (0.83)	0.44 (0.53)
II	16.79 (4.12)	8.11 (2.34)	8.51 (1.88)	2.95 (1.04)	1.25 (0.54)	0.44 (0.50)
III	16.30 (4.13)	7.90 (2.26)	8.24 (2.18)	2.89 (0.96)	1.10 (0.57)	0.44 (0.50)
IV–VI	15.30 (4.19)	7.60 (2.01)	7.70 (5.28)	2.60 (0.70)	1.20 (0.42)	0.40 (0.52)
Type of organ transplant, mean (SD)	***p=0.023****	*p=0.083*	***p=0.034****	*p=0.255*	*p=0.922*	*p=0.650*
Kidney	16.89 (3.59)	8.20 (1.97)	8.57 (1.88)	2.89 (0.92)	1.15 (0.57)	0.48 (0.50)
Liver	16.60 (4.48)	8.17 (2.29)	8.27 (2.20)	3.03 (1.07)	1.23 (0.57)	0.37 (0.49)
Heart	14.21 (4.43)	6.75 (2.63)	7.33 (2.44)	2.54 (0.88)	1.08 (0.58)	0.33 (0.48)
Lung	18.00 (4.47)	8.57 (2.76)	9.43 (1.27)	3.14 (1.07)	1.14 (0.69)	0.43 (0.54)
Multiple organs[b]	17.83 (3.59)	8.58 (2.07)	9.17 (1.64)	2.92 (1.17)	1.17 (0.58)	0.42 (0.52)
Duration of immunosuppression in years, mean (SD)	***p=0.005****	***p=0.029****	***p=0.007****	*p=0.080*	***p=0.047****	*p=0.668*
<3 years	19.38 (2.39)	9.75 (1.39)	9.38 (1.19)	3.38 (0.74)	1.25 (0.46)	0.50 (0.54)
3–10 years	16.53 (4.77)	8.02 (2.62)	8.27 (2.41)	2.93 (0.96)	1.33 (0.48)	0.38 (0.49)
10–20 years	15.68 (3.91)	7.62 (2.24)	8.03 (2.03)	2.68 (1.03)	1.03 (0.62)	0.42 (0.50)
>20 years	17.70 (2.84)	8.48 (1.52)	9.09 (1.52)	3.09 (0.84)	1.20 (0.54)	0.50 (0.51)

*p<0.05 indicates statistical significance, meaning that the probability of the observed result occurring by chance is less than 5%. Statistically significant results in boldface; a) Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol. 1988 Jun;124(6):869–71. doi: 10.1001/archderm.124.6.869. PMID: 3377516; b) Kidney and pancreas (n=4), kidney and liver (n=3), kidney and heart (n=2), kidney and lung (n=1), kidney, lung and heart (n=1), lung and liver (n=1). Note: Mann–Whitney U test and Kruskal–Wallis test were used. The assignment of items to the individual SCSK subscales is shown by colour (blue: sun protection, yellow: tanning, red: skin cancer-risk factors, green: skin cancer prevention, purple: symptoms of skin cancer). SCSK:Skin Cancer and Sun Knowledge; SD:standard deviation.

ratio in OTRs (2). In total, 48% of OTRs in our cohort had a personal history of skin cancer, mostly SCC. Nonetheless, only a minor proportion of OTRs acknowledged BCC (28.2%) or SCC (12.4%) as the most common type of skin cancer, and a substantial proportion of participants (44.6%) claimed that they did not know the answer to this particular question.

Our study revealed significant knowledge differences across the different types of transplanted organs with the lowest SCSK scores among heart transplant recipients – a finding of particular relevance in light of the typically more intense immunosuppressive therapy of heart transplant patients conveying increased skin cancer incidence and mortality compared with other OTRs (2, 29). Furthermore, longer duration of immunosuppression was associated with inferior skin cancer and sun protection knowledge in our study. These findings are particularly alarming as cumulative immunosuppressive therapy is a strong risk factor for KCs, which may arise with high cumulative numbers and dramatically accelerated dynamics in the post-transplantation period (2, 3, 5). Inferior knowledge over time may be attributable to diminishing reinforcement of education during prolonged post-transplant care or possible motivational decline in chronically ill patients (30). Supporting the necessity for ongoing, repeated educational interventions rather than one-time counselling, Thet et al. reported a significant increase in SCSK scores from baseline after an integrated skin cancer education programme in a small cohort of 25

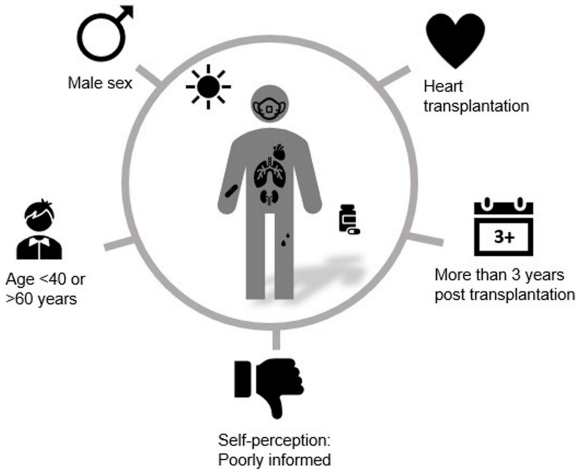

Fig. 1. Illustration of transplant-related and non-transplant-related variables significantly ($p<0.05$) associated with reduced skin cancer and sun protection knowledge.

renal transplant recipients, but improved knowledge was retained for only 6 months after education (17).

Interestingly, in contrast to transplant-related factors, demographic and behavioural variables, such as smoking and personal or family history of skin cancer, were not significantly associated with knowledge levels. Our findings are consistent with previous literature indicating that experiential factors do not always translate into improved understanding or behaviour change in sun protection (31–33) and emphasize the need for targeted educational strategies even in patients with previous skin cancer experience.

Sex and age were significantly associated with knowledge. Female patients had higher scores than males, confirming prior evidence that women tend to engage more in preventive health behaviours and score higher in health literacy assessments (18, 25). Knowledge deficits were most pronounced in the youngest (<40 years) and oldest (>60 years) participants. While, in older age groups, cognitive information retention issues or lower engagement with educational health literacy may play a role, younger individuals may perceive skin cancer as a distant threat and may be more influenced by social norms favouring tanning. While minors were not included in our study, insufficient sun-protective behaviours in younger adults have previously been reported (9, 25, 34).

Our findings demonstrate that despite regular specialized dermatologic care (89.8% of participants underwent regular skin cancer checks), knowledge deficits may persist in high-risk patient cohorts. Furthermore, despite frequent screening attendance, 26.0% of participants were insecure or felt insufficiently informed, underscoring persistent gaps in communication and education quality. Notably, however, patients who subjectively felt "well-informed" reached significantly higher SCSK scores in our study. Thus, while the SCSK scale proved to be a sensitive tool for detecting specific knowledge differences across patient subgroups, a quick preceding patient self-assessment may complement identification of patients needing more intensive education.

Educational interventions, particularly written material or mobile health interventions, have shown promise in improving sun protection knowledge and sun safety behaviours in immunosuppressed populations (25, 34, 35) with superior recall of UVR-protection advice if provided in a specialist clinical setting (15, 36). While the effectiveness of educational interventions translating into behaviour change and KC prevention has varied across different patient groups (12, 17, 31, 37), regular sunscreen use has been reported to effectively reduce the incidence of actinic keratosis and SCC in few randomized controlled trials and non-randomized prospective studies, in the general population and OTRs (1, 38–40). Associations between knowledge levels and protective behaviours were not assessed in the context of this study. Yet, from a clinical perspective, our findings support the integration of structured, educational strategies for sustained skin cancer and sun protection knowledge into specialized transplant aftercare, ideally including periodic re-education and addressing specific knowledge gaps, particularly for long-term transplant survivors.

Table IV. Correlation between self-assessment and skin cancer and sun knowledge scale and subscale scores

		SCSK subscale scores				
	SCSK-Score	**Sun protection**	**Tanning**	**Skin cancer risk factors**	**Skin cancer prevention**	**Symptoms of skin cancer**
Self-assessed information level, mean (SD)	***p=0.003****	***p=0.009****	***p=0.010****	***p=0.018****	*p=0.244*	*p=0.329*
Well-informed	17.06 (3.60)	8.25 (2.01)	8.62 (1.86)	2.96 (0.91)	1.18 (0.58)	0.47 (0.50)
Not well-informed	13.67 (3.93)	6.56 (2.33)	7.22 (1.93)	2.28 (1.02)	0.94 (0.54)	0.39 (0.50)
I don't know	16.46 (4.77)	8.11 (2.60)	8.32 (2.61)	2.93 (1.09)	1.18 (0.55)	0.32 (0.48)

*Statistically significant results ($P<0.05$) in boldface. Note: Mann-Whitney U test and Kruskal-Wallis test were used. The assignment of items to the individual SCSK subscales is shown by colour (blue: sun protection, yellow: tanning, red: skin cancer risk factors, green: skin cancer prevention, purple: symptoms of skin cancer).
SCSK:Skin Cancer and Sun Knowledge; SD:standard deviation.

Strengths and limitations

The SCSK-IS study addresses several research gaps: (*i*) paucity of robust data on UVR- and skin cancer-related knowledge in high-risk immunosuppressed populations such as OTRs; (*ii*) limited use of validated instruments like the SCSK scale in German-speaking populations; and (*iii*) a need for detailed subgroup analysis as a foundation for tailored prevention and education efforts. Strengths of this study further include a well-characterized, diverse cohort, comprehensive evaluation of multiple factors influencing knowledge and use of a culturally and linguistically validated questionnaire.

Limitations include the cross-sectional design, precluding causal inferences and potential biases inherent in self-report questionnaires, such as the desire to appear socially desirable, particularly when reporting sociodemographic characteristics. Although previously published studies using the SCSK scale were based on comparable or smaller sample sizes (10, 17, 23, 24), no formal power calculation was performed prior to recruitment in this study and the statistical power of the analyses should be interpreted with caution. Generalizability may be limited by a lack of ethnic diversity and the single country setting. The study setting at an academic centre offering specialized dermato-oncologic care may convey a selection bias towards patients with higher skin health interest. Finally, socioeconomic or academic backgrounds were not assessed.

Conclusion

This study highlights persistent knowledge gaps regarding UVR-specific skin cancer risks and preventive measures among OTRs despite routine specialized dermatological care in the post-transplantation period and emphasizes the need for targeted, longitudinal education strategies for high-risk patient populations. Future research should address the effectiveness of tailored educational interventions guided by SCSK assessment, and large-scale, longitudinal studies are needed to track knowledge retention over time and its effect on behaviour and skin cancer incidence. Furthermore, the integration of SCSK-based modules into digital health tools could facilitate scalable education across transplant centres.

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