



TROP-2 Is Not a Therapeutic Target in Melanoma: a Morphological Study

Sonia Fantone · Daniela Marzioni · Elisa Molinelli · Alessandra Filosa · Gaia Goteri ·

Anna Campanati · Roberto Campagna · Giovanni Tossetta

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ABSTRACT

Introduction: Cutaneous malignant melanoma represents only 1% of all skin cancers, but it has become a leading cause of cancer death, especially in young adults, owing to the high number of patients with disease progression and recurrence. In fact, disease progression and

recurrence is still an important issue in treatment of this disease. Trophoblast surface antigen-2 (TROP-2) is a type I transmembrane glycoprotein belonging to the epithelial cell adhesion molecule (EpCAM) family, a group of proteins involved in cell adhesion and anti-TROP-2 antibody–drug conjugate, and showed important beneficial effects in cancers. We hypothesized that if TROP-2 was expressed in melanomas, it could represent a therapeutic target.

Methods: In total, 50 primary melanomas at different stages and ten melanocytic nevi (used as control group) were analyzed for TROP-2 protein expression by immunohistochemistry and confocal microscopy.

Results: TROP-2 was expressed on the cell membranes of epidermal melanocytes and keratinocytes, while melanocytic nevi and melanoma tissues (at any stage) did not show TROP-2 expression.

Conclusions: Our findings suggest that TROP-2 could not be considered a therapeutic target for melanoma treatment because of the absence of detectable expression in the analyzed cohort.

Sonia Fantone and Daniela Marzioni equally contribute as co-first author.

Roberto Campagna and Giovanni Tossetta equally contribute as co-last author.

S. Fantone
Scientific Direction, IRCCS INRCA, 60124 Ancona, Italy

D. Marzioni
Department of Experimental and Clinical Medicine, Università Politecnica delle Marche, 60126 Ancona, Italy

E. Molinelli · A. Campanati (✉)
Department of Clinical and Molecular Sciences, Dermatology Clinic, Polytechnic Marche University, 60126 Ancona, Italy
e-mail: a.campanati@univpm.it

A. Filosa · G. Goteri
Department of Biomedical Sciences and Public Health, Section of Pathological Anatomy, Università Politecnica delle Marche, 60126 Ancona, Italy

R. Campagna · G. Tossetta
Department for the Promotion of Human Science and Quality of Life, San Raffaele Open University, 00166 Rome, Italy

Keywords: Melanoma; Trophoblast cell-surface antigen 2; TROP-2; Skin; Melanocytes; Keratinocytes

Key Summary Points

Why was the study undertaken?

This study aims to identify trophoblast surface antigen 2 (TROP-2) as a potential therapeutic target in melanoma because anti-TROP-2 antibody–drug conjugate showed important beneficial effects in many cancers.

What was learned from the study?

The study demonstrated that TROP-2 was expressed on the cell membrane of epidermal melanocytes and keratinocytes, while melanocytic nevi and melanoma tissues (at any stage) did not show TROP-2 expression.

The study clarified that TROP-2 could not be considered a therapeutic target for melanoma treatment because of the absence of detectable expression in the analyzed cohort.

INTRODUCTION

Although cutaneous malignant melanoma represents only 1% of all skin cancers, it has become a leading cause of cancer death especially in young adults [1–3]. The worse outcome of melanoma is also favored by the high number of patients with disease progression and recurrence [4]. In fact, although new and innovative therapies significantly improved the overall survival of patients with melanoma, disease progression and recurrence are still important issues in treatment of this disease [5, 6]. Among the risk factors for melanoma, aging is increasingly recognized as a critical predisposing factor, primarily attributable to the accumulation of senescent cells, particularly fibroblasts, in the skin. Senescent cells undergo profound alterations in chromatin architecture and gene expression profiles, leading to the production and secretion of a broad spectrum of factors that influence melanoma initiation [7]. Trophoblast surface antigen-2 (TROP-2) is a transmembrane glycoprotein of 323 amino acids belonging to the epithelial cell

adhesion molecule (EpCAM) family. TROP-2 protein is organized in an extracellular domain, a transmembrane domain and a cytoplasmic tail [8]. TROP-2 plays a key role in promoting cell proliferation and invasion, and it is expressed in several normal and pathological tissues [9–12]. Numerous studies have demonstrated that TROP-2 expression is significantly increased in several human cancers favoring cancer cell proliferation and invasion, then promoting cancer progression and a poor prognosis [9, 13–15]. The role of TROP-2 is mainly related to cell proliferation and mobility owing to the interaction of its extracellular domain with cell adhesion molecules, making itself an adhesion molecule [16]. In our previous study, we demonstrated that TROP-2 is involved in cutaneous inflammatory processes, suggesting a role in maintaining epithelial integrity [17]. It has been demonstrated that TROP-2 is also a druggable target. In fact, anti-TROP-2 antibody–drug conjugate showed important beneficial effects in patients with metastatic and non-metastatic cancers [18, 19].

We hypothesized that TROP-2 could be expressed in melanoma and melanocytic nevi and that TROP-2 could be considered as a potential therapeutic target.

METHODS

Patients

Our retrospective study included 60 formalin-fixed and paraffin-embedded (FFPE) specimens, obtained from the Department of Biomedical Sciences and Public Health (Section of Pathology) of the Università Politecnica delle Marche. The samples included 50 primary melanomas and 10 melanocytic nevi (used as control group). The study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments. Data collection and management observed the applicable rules, regulations, and directives concerning patient protection, such as patient privacy. Demographic and clinic-pathological data of patients have been reported in Table 1.

Table 1 Demographic and clinic-pathological data of patients

Categories	<i>N</i>
Cases	50
Sex	
Male	26
Female	24
Age (years)	
Mean	58
Range	21–82
Breslow thickness (mm)	
Mean	0.78
Range	0–3.8
Mitotic rate (mitoses/mm ²)	
No mitoses	18
1–5	18
> 5	14
Regression	
No	34
Yes	16
Ulceration	
No	38
Yes	12
Subtype	
Superficial spreading	18
Nodular	3
Lentiginous	14
Melanoma in situ	15

Immunohistochemistry

Paraffin sections (5 µm) were cut from FFPE tissue blocks, deparaffinized and rehydrated with xylene and a graded ethyl alcohol series. Sections were

rinsed in phosphate-buffered saline (PBS) and incubated with 3% hydrogen peroxide for 40 min at room temperature to block endogenous peroxidase. Thereafter, 10 mM citrate buffer (pH 6.0) at 98 °C for 10 min was used as antigen retrieval. Animal-Free Blocker (Vector Laboratories, Burlingame, CA, USA) diluted 1:5 in PBS for 20 min was used to block nonspecific background. Subsequently, sections were incubated with mouse monoclonal anti-TROP-2 antibody (sc-376746; Santa Cruz Biotechnology, TX, USA) diluted 1:300 and incubated overnight at 4 °C. Sections were incubated with anti-mouse biotinylated antibody diluted 1:200 (Vector Laboratories) for 30 min after washing. The avidin–biotin–peroxidase complex (ABC) method (Vector Laboratories) was performed using 3′,3′-diaminobenzidine hydrochloride (Sigma-Aldrich, St. Louis, MO, USA) as the chromogen. Sections were counterstained with Mayer’s hematoxylin, dehydrated and mounted with Eukitt solution (Kindler GmbH and Co., Freiburg, Germany). Negative controls were performed by omitting the first or secondary antibody and using an isotype control antibody (ab18443; Abcam, Cambridge, UK) at the same dilution of primary antibody for all the immunohistochemical reactions performed in this study.

Immunofluorescence Staining

Section rehydration and antigen retrieval were performed as reported in the immunohistochemistry section. After washing with PBS, tissue autofluorescence was blocked by incubating sections for 30 min with 0.1% Sudan Black B stain (SBB). Animal-Free Blocker (Vector laboratories) diluted 1:5 in PBS for 30 min at room temperature was used to block nonspecific binding sites. Subsequently, sections were incubated with the primary antibodies mouse anti-TROP-2 (1:300; sc-376746, Santa Cruz Biotechnology) and rabbit anti-SOX10 (1:400; A700-080, ThermoFisher Scientific, MA, USA) at 4 °C overnight. After washing, sections were incubated with the secondary antibodies anti-mouse conjugated with Alexa Fluor-488 and anti-rabbit conjugated with Alexa Fluor-555 (both from Invitrogen, Carlsbad, CA, USA) diluted 1:400 for 1 h at room temperature. Nuclei were visualized by using

DAPI (Invitrogen). Sections were mounted with Vectashield mounting medium (Vector Laboratories). Negative controls were performed by omitting the first or secondary antibody or using an isotype control antibody (ab172730 and ab18443; Abcam, Cambridge, UK) at the same dilution of primary antibody. Sections were visualized with the inverted microscope Eclipse Ti2-E supplied with an AX confocal system (Nikon, Japan).

RESULTS

Histological Examination

Hematoxylin and eosin staining of melanocytic nevus (Fig. 1a), melanoma in situ (Fig. 1b),

pT1a melanoma (Fig. 1c), and pT3b melanoma (Fig. 1d) tissues were examined to verify the diagnosis. The representative sample of normal skin (Fig. 1a) shows the normal distribution of melanocytes among basal keratinocytes. In melanoma in situ (Fig. 1b), an increased number of melanocytes can be noted that are disarrayed, atypical in shape, and with a tendency in pagetoid spreading among keratinocytes. In pT1a melanoma (Fig. 1c), the junctional appearance is the same as melanoma in situ with the presence of a single nest of neoplastic melanocytes invading the papillary dermis. Thicker melanomas such as pT3b (Fig. 1d) show a predominant vertical growth phase in the reticular dermis, composed of confluent sheets of malignant melanocytes.

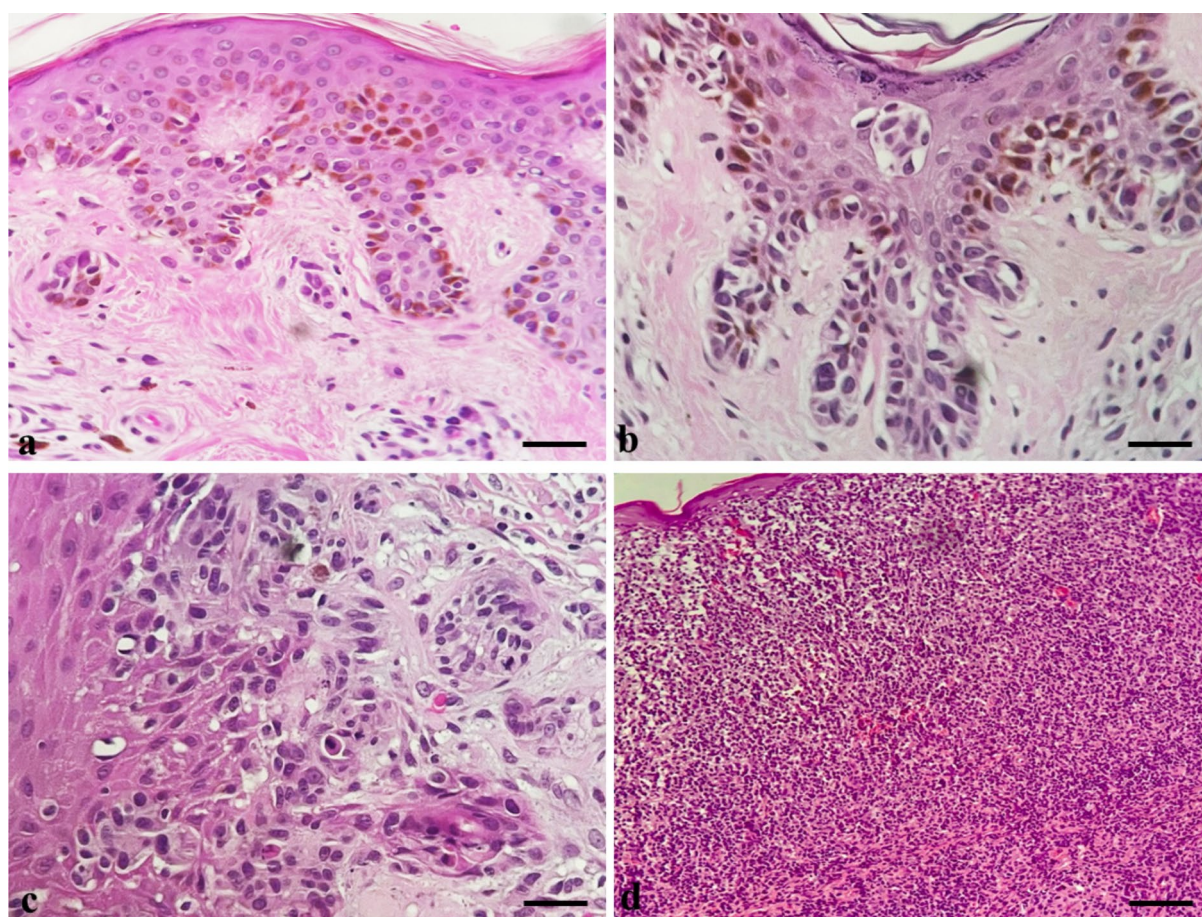


Fig. 1 Hematoxylin and eosin staining of normal skin (a), in situ (b), pT1a (c), and pT3b (d) melanoma. a–c bars = 100 µm; d 200 µm

Immunohistochemical Analysis

We evaluated TROP-2 expression in melanocytic nevi and melanoma tissues by using immunohistochemical analysis. TROP-2 was expressed on the cell membranes of epidermal keratinocytes (Fig. 2a–d), while melanocytic nevi (Fig. 2a) and in situ (Fig. 2b), pT1a (Fig. 2c), and pT3b (Fig. 2d) melanoma tissues did not show TROP-2 expression.

Immunofluorescence Analysis

As the presence of melanin produced by melanocytes may alter the interpretation of TROP-2 staining obtained by immunohistochemistry, we performed immunofluorescence

analysis using SOX10 nuclear protein as marker of melanocytes [20]. Interestingly, we found that epidermal melanocytes (Fig. 3a, red arrows) expressed TROP-2 protein (Fig. 3, in green). However, melanocytes of melanocytic nevi did not express TROP-2 protein (Fig. 3b). In addition, no TROP-2 expression was found in melanoma tissues at any stage (Fig. 3c–e).

DISCUSSION

Despite the low incidence of cutaneous malignant melanoma, the mortality rate of this type of cancer increased in the recent years [21]. In addition, disease progression and recurrence significantly affect the overall survival of these

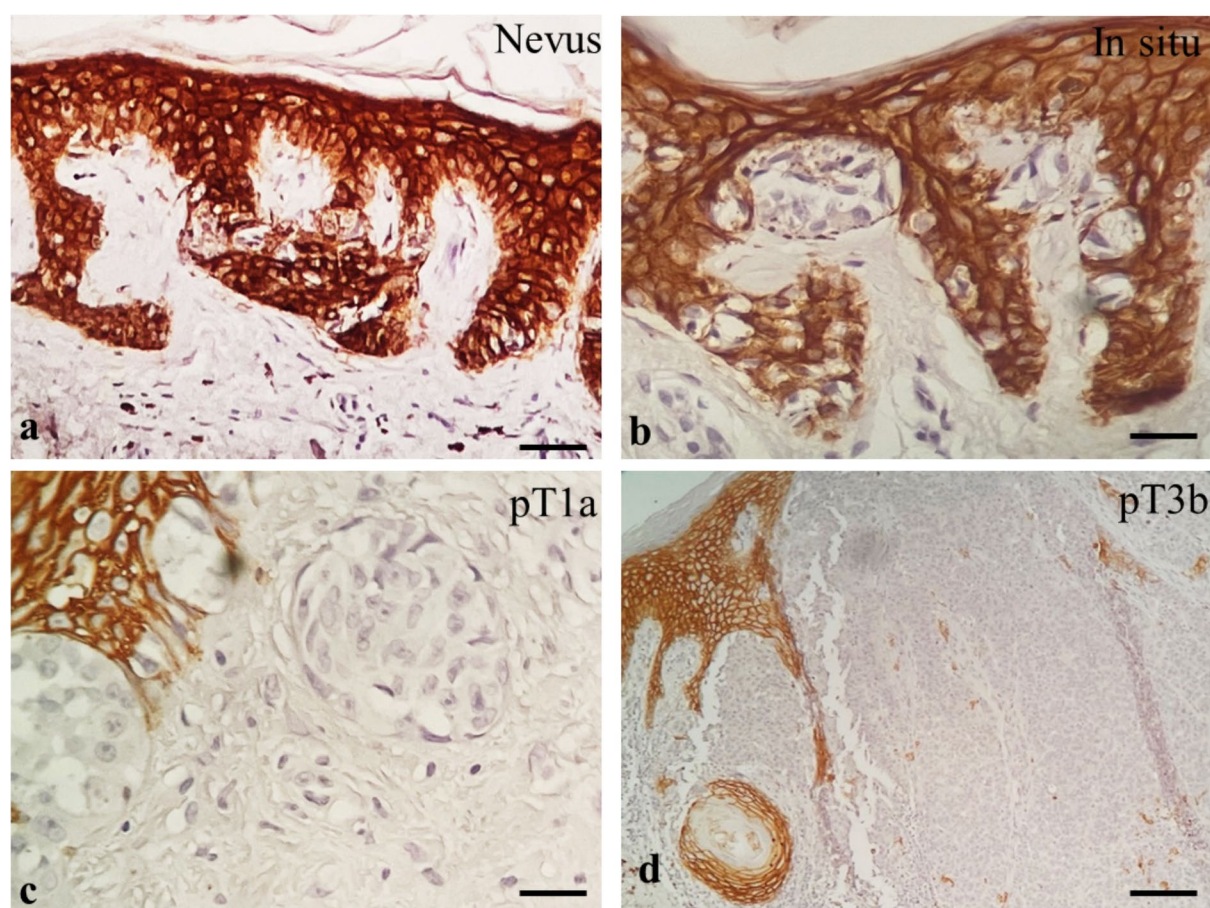


Fig. 2 Immunohistochemical staining of trophoblast surface antigen-2 (TROP-2) expression in melanocytic nevus (a), in situ (b), pT1a (c), and pT3b (d) melanoma samples. a bar = 100 μ m; b, c bars = 50 μ m; d, bar = 200 μ m

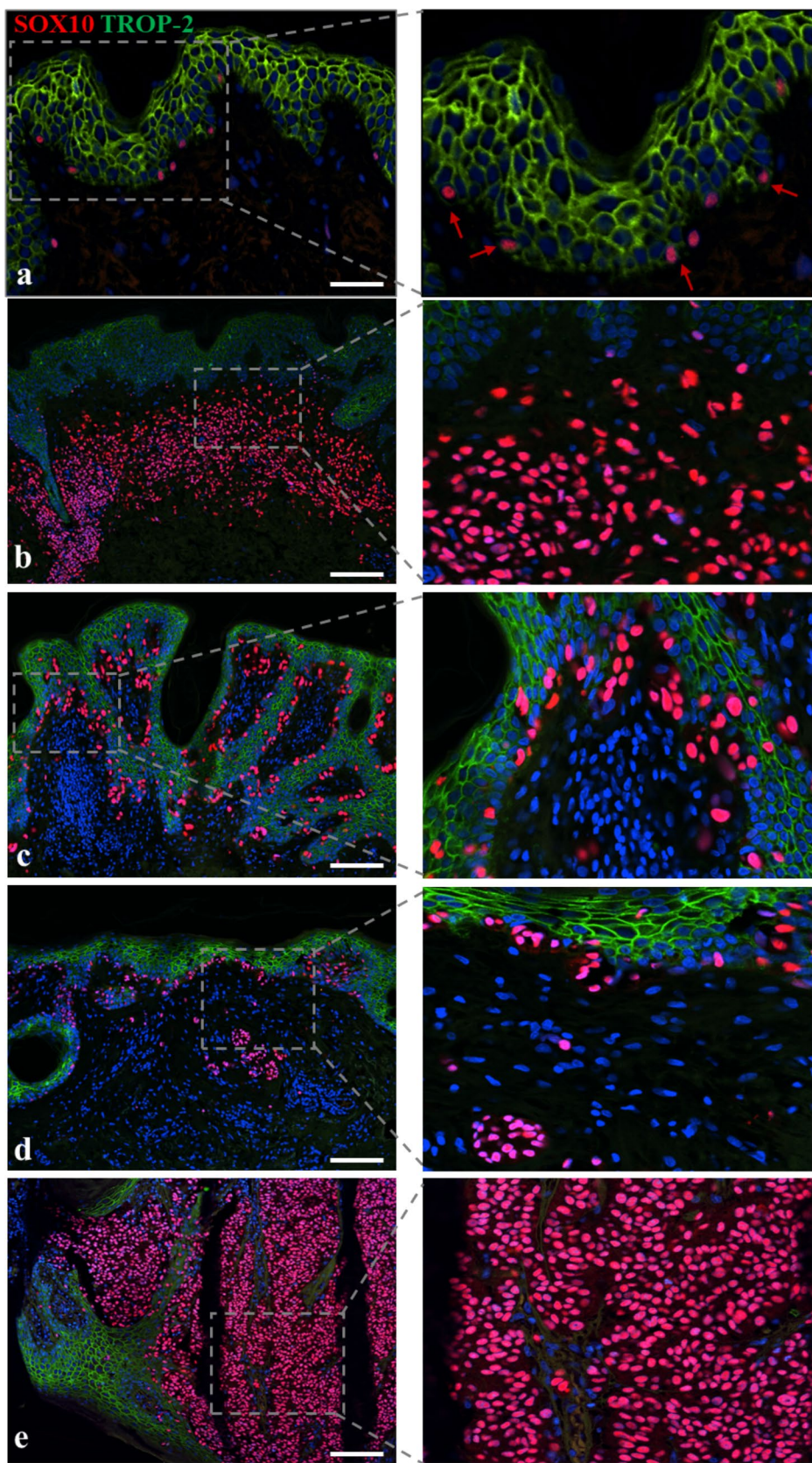


Fig. 3 Immunofluorescence analysis of trophoblast surface antigen-2 (TROP-2) expression in normal skin (a), melanocytic nevus (b), in situ (c), pT1a (d), and pT3b (e) melanoma samples. TROP-2 is shown in green, and it is detected in the cell membrane. SOX10 (melanocyte marker) is shown in red, and it is detected in nuclei. The nuclei have been stained with DAPI (blue). Red arrows show epidermal melanocytes double stained with SOX10 and TROP-2 (a). a bar = 55 μ m; b–e bars = 200 μ m

patients [1–3]. TROP-2 is highly expressed in several malignancies including breast, bladder, lung, and prostate cancers, where it plays a key role in cancer proliferation, migration, and invasion, making this protein a good therapeutic target for these malignancies [22–26].

TROP-2-targeted therapeutics mainly consist in antibody–drug conjugates (ADC), small-molecule cytotoxic drugs conjugated to monoclonal antibodies that recognize targeted protein expressed on the surface of cancer cells [27]. Several ADCs targeting TROP-2 have been approved for marketing by Food and Drug Administration (FDA) including sacituzumab govitecan (Trodelvy) and datopotamab deruxtecan (Dato-DXd) [22]. In our study, we evaluated TROP-2 immunoreactivity in normal skin, melanocytic nevi, and melanoma tissues at different stages to evaluate TROP-2 as a potential therapeutic target in melanoma.

A recent study by He and colleagues demonstrated the absence of TROP-2 expression in melanoma (25 cases) [28], with their data in agreement with our findings. However, He and colleagues did not specify which stages were investigated. Moreover, they did not report whether TROP-2 was expressed in the nevi (which should be used as control to compare melanoma TROP-2 expression) and whether epidermal melanocytes express TROP-2.

Although it has been widely demonstrated the key role of TROP-2 in inhibiting cell adhesion (e.g., by interacting with integrin β -1 and RACK1) in cancer cells [29], its role in adhesion of normal cells is still poorly understood. Our study demonstrated TROP-2 expressions on the cell membranes of epidermal keratinocytes and epidermal melanocytes, suggesting a role of TROP-2 in maintaining epidermal melanocyte–keratinocyte interaction. This hypothesis

is supported by the fact that TROP-2 can bind claudin-1 and claudin-7, two important tight junction proteins, potentially strengthening cell–cell junctions [30].

Interestingly, our findings also showed that melanocytic nevi and melanoma tissues (from the in situ to pT3b stage) did not express TROP-2 protein, suggesting that this protein may not be involved in melanoma pathogenesis. Thus, we suggest that TROP-2 could not be considered a therapeutic target for melanoma treatment because of the absence of detectable expression in the analyzed cohort. In addition, the latter is a relatively limited cohort and lacks very thick or metastatic melanomas that can represent the limitations of the current study. Furthermore, since very thick or metastatic melanomas represent the most advanced stages of the disease, they could theoretically present different molecular profiles.

CONCLUSIONS

While TROP-2 is a promising therapeutic target in skin malignancies such as cutaneous squamous cell carcinoma (cSCC) [31], sebaceous carcinoma, and sweat gland carcinoma [32], TROP-2-targeted therapy may not exert beneficial effects in Merkel cell carcinoma, atypical fibroxanthoma, and melanoma [28] as TROP-2 is not expressed in these malignancies. Our data also demonstrated that TROP-2-targeted therapy may not exert beneficial effects in patients with melanoma at early stages. Therefore, innovative therapies not focused on TROP-2 are necessary to improve the outcome of patients with melanoma.

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contributions to the study design, development of the study protocol, study conceptualization, and data interpretation. The first draft of the manuscript was written by Giovanni Tossetta, and all authors commented on previous versions of the manuscript. All authors read and approved of the final manuscript.

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Data Availability. The datasets generated during the current study are available from the corresponding author on reasonable request.

Declarations

Conflicts of Interest. Anna Campanati is an Editorial Board member of *Dermatology and Therapy*. Anna Campanati was not involved in the selection of peer reviewers for the manuscript nor any of the subsequent editorial decisions. Sonia Fantone, Daniela Marzioni, Elisa Molinelli, Alessandra Filosa, Gaia Goteri, Roberto Campagna, and Giovanni Tossetta declare no conflicts of interest.

Ethics Approval. Institutional review board approval was waived for this study, as the procedures adopted did not deviate from standard clinical practice. All patients provided written informed consent to have their data collected during routine clinical practice included in this retrospective study, for the retrospective retrieval of anonymized data. The study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments. Data collection and management observed the applicable rules, regulations, and directives concerning patient protection, such as patient privacy.

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REFERENCES

1. Molinelli E, Ceccarelli G, Fantone S, et al. Melanoma and subcutaneous adipose tissue: role of peritumoral adipokines in disease characterization and prognosis. *Pigment Cell Melanoma Res.* 2023;36(5):423–30. <https://doi.org/10.1111/pcmr.13103>.
2. Emanuelli M, Sartini D, Molinelli E, et al. The double-edged sword of oxidative stress in skin damage and melanoma: from physiopathology to therapeutic approaches. *Antioxidants (Basel)*. 2022. <https://doi.org/10.3390/antiox11040612>.
3. Ganzetti G, Sartini D, Campanati A, et al. Nicotinamide N-methyltransferase: potential involvement in cutaneous malignant melanoma. *Melanoma Res.* 2018;28(2):82–8. <https://doi.org/10.1097/CMR.0000000000000430>.
4. Sartini D, Molinelli E, Pozzi V, et al. Immunohistochemical expression of nicotinamide N-methyltransferase in lymph node metastases from cutaneous malignant melanoma. *Hum Cell.* 2023;36(1):480–2. <https://doi.org/10.1007/s13577-022-00793-3>.
5. Lowe MC, Delman KA, Ollila DW. The landmark series: melanoma and adjuvant therapy. *Ann Surg Oncol.* 2025. <https://doi.org/10.1245/s10434-025-17102-5>.
6. Ferrari M, Facchini BA, Ascierto PA, et al. Melanoma neoadjuvant treatment: review and update of recent trials. *Expert Rev Anticancer Ther.* 2025. <https://doi.org/10.1080/14737140.2025.2474182>.
7. Basu A, Farsam V, Singh K, et al. Senescent fibroblasts drive melanoma progression through GCP-2

- induced CREB phosphorylation enhancing glycolysis. *Aging Cell*. 2025;24(12):e70239. <https://doi.org/10.1111/accel.70239>.
8. Lenart S, Lenart P, Smarda J, et al. Trop2: jack of all trades, master of none. *Cancers (Basel)*. 2020. <https://doi.org/10.3390/cancers12113328>.
 9. Liu Y, Huang W, Saladin RJ, et al. Trop2-targeted molecular imaging in solid tumors: current advances and future outlook. *Mol Pharm*. 2024;21(12):5909–28. <https://doi.org/10.1021/acs.molpharmaceut.4c00848>.
 10. Zhao Y, Wu Z. TROP2 promotes PINK1-mediated mitophagy and apoptosis to accelerate the progression of senile chronic obstructive pulmonary disease by up-regulating DRP1 expression. *Exp Gerontol*. 2024;191:112441. <https://doi.org/10.1016/j.exger.2024.112441>.
 11. Szabo R, Ward JM, Artunc F, et al. EPCAM and TROP2 share a role in claudin stabilization and development of intestinal and extraintestinal epithelia in mice. *Biol Open*. 2022. <https://doi.org/10.1242/bio.059403>.
 12. Tsukahara Y, Tanaka M, Miyajima A. TROP2 expressed in the trunk of the ureteric duct regulates branching morphogenesis during kidney development. *PLoS ONE*. 2011;6(12):e28607. <https://doi.org/10.1371/journal.pone.0028607>.
 13. Liu X, Ma L, Li J, et al. Trop2-targeted therapies in solid tumors: advances and future directions. *Theranostics*. 2024;14(9):3674–92. <https://doi.org/10.7150/thno.98178>.
 14. Goldstein AS, Lawson DA, Cheng D, et al. Trop2 identifies a subpopulation of murine and human prostate basal cells with stem cell characteristics. *Proc Natl Acad Sci USA*. 2008;105(52):20882–7. <https://doi.org/10.1073/pnas.0811411106>.
 15. Garraway IP, Sun W, Tran CP, et al. Human prostate sphere-forming cells represent a subset of basal epithelial cells capable of glandular regeneration in vivo. *Prostate*. 2010;70(5):491–501. <https://doi.org/10.1002/pros.21083>.
 16. Balzar M, Briaire-de Bruijn IH, Rees-Bakker HA, et al. Epidermal growth factor-like repeats mediate lateral and reciprocal interactions of Ep-CAM molecules in homophilic adhesions. *Mol Cell Biol*. 2001;21(7):2570–80. <https://doi.org/10.1128/MCB.21.7.2570-2580.2001>.
 17. Tossetta G, Fantone S, Filosa A, et al. Psoriasis and lichen planus: an immunohistochemical study of trophoblast cell-surface antigen 2 expression in skin biopsies. *Hum Cell*. 2025;38(6):179. <https://doi.org/10.1007/s13577-025-01313-9>.
 18. Goldenberg DM, Cardillo TM, Govindan SV, et al. Trop-2 is a novel target for solid cancer therapy with sacituzumab govitecan (IMMU-132), an antibody–drug conjugate (ADC). *Oncotarget*. 2015;6(26):22496–512. <https://doi.org/10.18632/oncotarget.4318>.
 19. Foersch S, Schmitt M, Litmeyer AS, et al. TROP2 in colorectal carcinoma: associations with histopathology, molecular phenotype, and patient prognosis. *J Pathol Clin Res*. 2024;10(5):e12394. <https://doi.org/10.1002/2056-4538.12394>.
 20. Bahmad HF, Thiravialingam A, Sriganeshan K, et al. Clinical significance of SOX10 expression in human pathology. *Curr Issues Mol Biol*. 2023;45(12):10131–58. <https://doi.org/10.3390/cimb45120633>.
 21. Campagna R, Salvolini E, Pompei V, et al. Nicotinamide N-methyltransferase gene silencing enhances chemosensitivity of melanoma cell lines. *Pigment Cell Melanoma Res*. 2021;34(6):1039–48. <https://doi.org/10.1111/pcmr.12993>.
 22. Li XX, Chen JL. TROP2: as a promising target in lung cancer. *Front Oncol*. 2025;15:1569897. <https://doi.org/10.3389/fonc.2025.1569897>.
 23. Sperger JM, Helzer KT, Stahlfeld CN, et al. Expression and therapeutic targeting of TROP-2 in treatment-resistant prostate cancer. *Clin Cancer Res*. 2023;29(12):2324–35. <https://doi.org/10.1158/1078-0432.CCR-22-1305>.
 24. Hu Y, Zhu Y, Qi D, et al. Trop2-targeted therapy in breast cancer. *Biomark Res*. 2024;12(1):82. <https://doi.org/10.1186/s40364-024-00633-6>.
 25. Avellini C, Licini C, Lazzarini R, et al. The trophoblast cell surface antigen 2 and miR-125b axis in urothelial bladder cancer. *Oncotarget*. 2017;8(35):58642–53. <https://doi.org/10.18632/oncotarget.17407>.
 26. Cubas R, Zhang S, Li M, et al. Trop2 expression contributes to tumor pathogenesis by activating the ERK MAPK pathway. *Mol Cancer*. 2010;9:253. <https://doi.org/10.1186/1476-4598-9-253>.
 27. Perez HL, Cardarelli PM, Deshpande S, et al. Antibody–drug conjugates: current status and future directions. *Drug Discov Today*. 2014;19(7):869–81. <https://doi.org/10.1016/j.drudis.2013.11.004>.
 28. He LJ, Wang Y, Curry JL, et al. TROP2 is highly expressed in cutaneous squamous cell carcinomas and a subset of adnexal carcinomas: a potential therapeutic target with TROP2-directed antibody drug conjugates. *Hum Pathol*. 2025. <https://doi.org/10.1016/j.humpath.2025.105853>.

29. Trerotola M, Li J, Alberti S, et al. Trop-2 inhibits prostate cancer cell adhesion to fibronectin through the beta1 integrin-RACK1 axis. *J Cell Physiol.* 2012;227(11):3670–7. <https://doi.org/10.1002/jcp.24074>.
30. Nakatsukasa M, Kawasaki S, Yamasaki K, et al. Tumor-associated calcium signal transducer 2 is required for the proper subcellular localization of claudin 1 and 7: implications in the pathogenesis of gelatinous drop-like corneal dystrophy. *Am J Pathol.* 2010;177(3):1344–55. <https://doi.org/10.2353/ajpath.2010.100149>.
31. Tanegashima K, Tanaka Y, Ito T, et al. TROP2 expression and therapeutic implications in cutaneous squamous cell carcinoma: insights from immunohistochemical and functional analysis. *Exp Dermatol.* 2024;33(10):e15196. <https://doi.org/10.1111/exd.15196>.
32. Ito T, Hashimoto H, Tanaka Y, et al. TROP2 expression in sebaceous and sweat gland carcinoma. *J Clin Med.* 2022. <https://doi.org/10.3390/jcm11030607>.

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