**Original paper**

*Cite as: Przybysz P, Jackowska T, Wilińska M, Malinowska S, Wójtowicz J, Mlosek RK: Ultrasound image of healthy skin in newborns in the first 24 hours of life. J Ultrason 2020; 20: e242–e247. doi: 10.15557/JoU.2020.0043.*

**Submitted:** 27.09.2020
**Accepted:** 10.11.2020
**Published:** 18.12.2020

# Ultrasound image of healthy skin in newborns in the first 24 hours of life

Paulina Przybysz[1], Teresa Jackowska[1], Maria Wilińska[2], Sylwia Malinowska[3], Joanna Wójtowicz[1], Robert Krzysztof Mlosek[4]

[1] *Department of Paediatrics, Centre of Postgraduate Medical Education, Warsaw, Poland*
[2] *Department of Neonatology, Centre of Postgraduate Medical Education, Warsaw, Poland*
[3] *Life-Beauty s.c., Grodzisk Mazowiecki, Poland*
[4] *Ultrasound Diagnostic Department Faculty of Medical Sciences, Medical University of Warsaw, Warsaw, Poland*

*Correspondence: Paulina Przybysz, Department of Paediatrics, Centre of Postgraduate Medical Education, Cegłowska 80 Str., 01-809 Warsaw, Poland; tel.: +48 509 099 718, e-mail: paulina.m.przybysz@gmail.com*

DOI: 10.15557/JoU.2020.0043

**Keywords**
epidermis, dermis, subcutaneous tissue, skin ultrasound, newborn

**Abstract**

**Introduction:** Ultrasound imaging is a safe, repeatable and easily available imaging procedure. Based on these qualities, it may become a useful tool for skin assessment in newborns. **Aims:** The aim of the study was to evaluate the usefulness of high-frequency ultrasound imaging for neonatal skin assessment. Another aim was to identify differences in ultrasound features of the skin in newborns depending on the examination site, sex, age, birth weight, and arterial blood gas results. **Material and method:** A total of 72 newborns in the first 24 hours of life, without any skin lesions, were included in the study. All newborns underwent ultrasound skin examinations in three body sites (forearm, abdomen and thigh) during the first 24 hours of life. DermaMed Ultrasound Scanner with a 48 MHz probe was used for imaging. A total of three structures were identified in the ultrasound images: epidermal echo, dermis, and subcutaneous tissue. The study assessed the thickness of the epidermis and dermis, and the echogenicity of the dermis and subcutaneous tissue. Data were analysed to determine possible links with sex, post-conceptional age, body weight, birth route, and results of umbilical cord blood gas analysis. **Results:** Depending on the body site examined, the mean epidermal thickness was 0.081 to 0.083 mm, while the mean thickness of the dermis ranged between 0.679 and 0.722 mm. The newborns with higher birth weights were shown to have a thicker epidermis regardless of the examined site [$R$ (correlation coefficient) for the forearm: 0.47 ($p$ <0.001), abdomen: 0.53 ($p$ <0.001), thigh: 0.48 ($p$ <0.001)]. A positive correlation was found between epidermal and dermal thickness (R = 0.34; $p$ = 0.004), but a comparison of the three examined sites revealed no significant differences in the thickness of the two structures. The sex of the newborn had no significant effect on the ultrasound features of the skin. None of the ultrasound parameters under study was found to correlate with the pH level in umbilical cord blood gas analysis. Subcutaneous oedema was detected in the examined sites in all the newborns studied. **Conclusions:** High-frequency ultrasound imaging may become a useful method for neonatal skin assessment, complementing existing diagnostic techniques for monitoring pathologically altered skin.

## Introduction

The skin is the largest organ of the human body, performing multiple mechanical and physiological functions[1]. The anatomy and physiology of the skin change with age from birth to old age. At birth, neonates change their living environment from aquatic (intrauterine) to atmospheric (extrauterine). In addition to vitally important changes in the circulatory and respiratory systems, complex adaptation processes also take place in the skin[2]. During the intrauterine period, foetal skin is covered with vernix caseosa, which is removed during birth and through mechanical hygienic procedures performed in newborns. The first physical examination in neonates often reveals congenital skin pathologies (haemangiomas, skin moles, discolorations)[3]. High-frequency ultrasound imaging (HF-US) is a non-invasive and safe technique allowing quick and repeatable assessment of observed pathologies[4]. However, the majority of literature reports and scientific studies describing the applications of HF-US in various fields of medicine refer to the adult population. Children are rarely addressed in this context, and the few available studies focus on older paediatric groups. Using HF-US for the early diagnosis of congenital skin lesions requires establishing the benchmark, i.e. determining both the characteristics and methods for neonatal skin assessment by ultrasound imaging. Potential differences in the ultrasound image of the skin after birth may be attributed to adaptive processes.

## Aim of study

The aim of the study was to assess the usefulness of HF-US for the imaging assessment of skin in newborns, and to identify possible differences in ultrasound features of the skin and subcutaneous tissue depending on neonatal birth weight, post-conceptional age, sex, and general condition of the newborn immediately after birth, assessed by umbilical cord blood gas analysis (pH).

## Study hypothesis

The ultrasound features of the skin and subcutaneous tissue in newborns in the first 24 hours of life differ from the reported ultrasound characteristics of healthy skin in other age groups. The differences can be attributed to the neonate's transition from intrauterine to extrauterine life at birth, associated adaptive processes, and skin maturation in the prenatal and postnatal periods. The ultrasound image of the skin in newborns varies depending on their birth weight, sex, post-conceptional age, as well as the general condition of the newborn at birth.

## Material and methods

A total of 72 Caucasian neonates in the first 24 hours of life (6 to 24 hours after birth) were enrolled in the study. The group comprised healthy, full-term newborns (post-conceptional age from full 37 to 41 weeks of gestation), in good general condition, with a minimum APGAR score of 8 at birth, and without skin pathologies visible on physical examination. There were 34 (47%) female and 38 (53%) male newborns. One newborn was excluded from further analysis because of the low quality of ultrasound images attributable to the child's anxiety during the examination as well as motion artefacts (measurements could not be performed).

In all newborns, HF-US of the skin and subcutaneous tissue was performed in the same three body sites: on the outer third of the proximal surface of the extended forearm, on the distal lateral third of the thigh surface (with the knee flexed at approximately 90°), and on the abdomen at the level of the navel in the midclavicular line (in the supine position). Additional study material comprised data derived from the children's medical records including birth weight, sex, post-conceptional age, and the pH of arterial cord blood.

All skin examinations were performed using DermaMed Ultrasound Scanner with a 48 MHz probe. B-mode images were acquired. A total of three structures were identified including the epidermal echo, dermis, and subcutaneous tissue. The thickness of the epidermis and dermis, and the echogenicity of the dermis and subcutaneous tissue, were assessed.

In order to minimise measurement errors, epidermal and dermal thickness was determined with Dramiński DermaMed software which provides multiple measurements of the thickness of assessed skin layers on the basis of differences in their echogenicity. In the next step, the mean was calculated from the above measured values and analysed further (Fig. 1). All thickness measurements acquired for different skin layers were rounded to the nearest thousandth of a millimetre. Echogenicity was measured by designating a region of interest (ROI) within the assessed layer. Within the ROI, the number of all pixels and the number of pixels in the predefined value range (0–30, for oedema in the subcutaneous tissue: 0–80) were summed up. In the next stage, a percentage ratio of pixels in the predefined value range to all pixels was calculated.

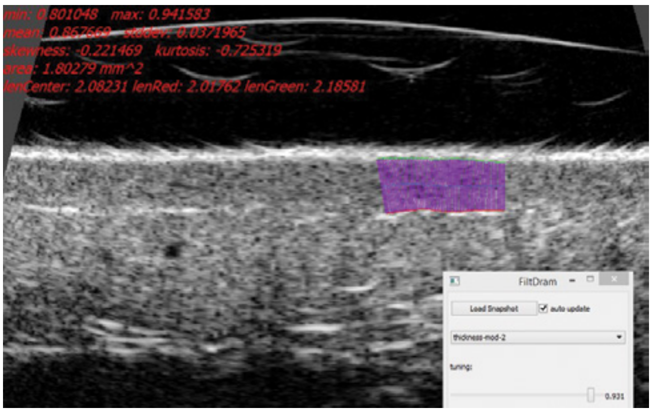


**Fig. 1.** *Automatic measurement of subcutaneous tissue thickness in the ultrasound image using Dramiński software (DermaMed)*

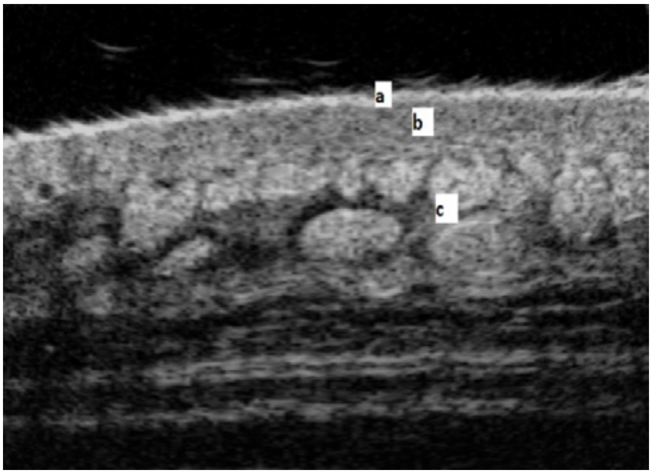


**Fig. 2.** *Ultrasound image of the skin in a newborn in the first 24 hours of life (thigh area), DermaMed unit with a 48 MHz probe. a – epidermis; b – dermis; c – subcutaneous tissue*

Consequently, it was possible to compare the values across the examined body sites and between the newborns.

All measurements were carried out by one examiner and saved in a database. The study was approved by the Bioethics Committee (Decision no. 42/PB/2016, 8 June 2016). Before newborn babies were included in the study, written consent was obtained from their legal guardians. The newborns' guardians had an opportunity to ask questions, and were provided by the investigator with comprehensive information about the study.

The study was conducted with the Centre of Postgraduate Medical Education grant no. 506-1-020-01-19.

## Statistics

The statistical evaluation of the results was performed with statistical tests available in Statistica 10 software (StatSoft). The Shapiro-Wilk test was used to determine the distribution of variables. The proposed null hypothesis was that there was no relationship between the studied variables, and the correlation coefficient ($R$) would be equal to 0. The relationships between variables were assessed, and the correlation was calculated (Pearson's correlation significance test or Spearman's correlation significance test) across the studied groups depending on the body site examined (abdomen, thigh, outer surface of the forearm) for the following parameters: epidermal thickness, dermal thickness, echogenicity of the dermis, echogenicity of the subcutaneous tissue. Kruskal-Wallis test with Dunn's post hoc test was also used for specific comparisons, with $\alpha = 0.05$ adopted as the level of statistical significance.

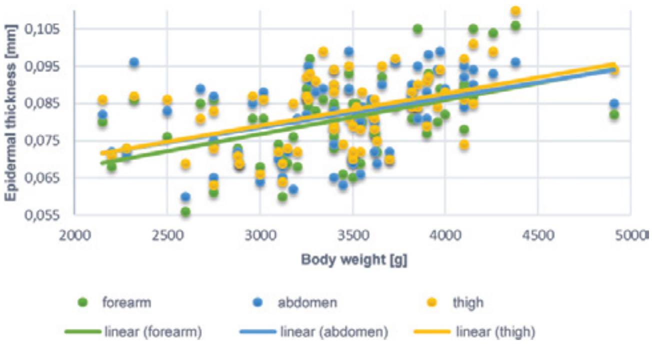


**Fig. 3.** *Relationship between epidermal thickness and body weight in all examined sites*

**Tab. 1.** *Relationship between epidermal thickness and body weight in all examined sites*

| | Forearm | Abdomen | Thigh |
|---|---|---|---|
| ***R*** | 0.47 | 0.53 | 0.48 |
| ***p*** | <0.001 | <0.001 | <0.001 |

## Results

Based on skin anatomy, epidermal echo, dermis, and subcutaneous tissue (Fig. 2) were identified in the ultrasound images recorded in all examined body sites. Detailed data analysis was carried out separately for each of the parameters under study.

### Epidermal echo

Measurements of epidermal thickness showed that newborns with a higher birth weight had a thicker epidermis in all body sites examined (Fig. 3, Tab. 1). The mean thickness of the epidermis on the forearm and thigh was 0.081 mm and 0.083 mm, respectively. The median epidermal thickness on the abdomen was 0.084 mm (Tab. 2). Analysis of post-conceptional age revealed that children born later in pregnancy has a thicker epidermis: $R$ (forearm) = 0.39 ($p = 0.004$), $R$ (abdomen) = 0.43 ($p = 0.002$), $R$ (thigh) = 0.35 ($p = 0.013$) (Tab. 3). Epidermal thickness determined in the first 24 days of life was found to be unrelated to the route of birth or general condition of the foetus assessed by umbilical cord blood gas analysis (pH) immediately after birth. No statistically significant differences were found when comparing epidermal thickness in girls and boys regardless of the body areas examined. Differences in the thickness of the epidermis across the examined body sites were statistically insignificant.

### Dermis

The median thickness of the dermis on the forearm was 0.722 mm, on the abdomen – 0.716 mm, and on the thigh – 0.679 mm (Tab. 2). The results obtained for dermal thickness in the thigh area were shown to be positively correlated with birth weight ($R = 0.33$, $p = 0.017$) (Fig. 4). Based on other body sites examined, it was demonstrated that children with higher birth weights had a thicker dermis, though the relationship was statistically insignificant. Also, there was no significant correlation between the thickness of the dermis and its echogenicity depending on sex, birth route or the pH value of umbilical cord arterial blood. HF-US findings recorded in the thigh area showed a significant correlation between epidermal and dermal thickness ($R = 0.34$; $p = 0.004$). In newborns with a thicker epidermis, the dermis was also found to be thicker. The echogenicity of the dermis was significantly lower in the abdominal area compared

**Tab. 2.** *Epidermal and dermal thickness [mm] in newborns in the first 24 hours of life in three examined sites – on the outer side of the forearm, on the abdomen, and on the thigh (epidermal thickness values on the forearm and thigh were normally distributed, while other values were non-normally distributed)*

| | Forearm | | Abdomen | | Thigh | |
|---|---|---|---|---|---|---|
| | epidermis | dermis | epidermis | dermis | epidermis | dermis |
| **Minimum** | 0.056 | 0.577 | 0.060 | 0.511 | 0.063 | 0.478 |
| **25% Percentile** | 0.073 | 0.676 | 0.072 | 0.641 | 0.073 | 0.617 |
| **Median** | 0.081 | **0.722** | **0.084** | **0.716** | 0.084 | **0.679** |
| **75% Percentile** | 0.086 | 0.769 | 0.090 | 0.786 | 0.090 | 0.781 |
| **Maximum** | 0.106 | 0.990 | 0.099 | 1.196 | 0.110 | 1.180 |
| **Mean** | **0.081** | 0.734 | 0.082 | 0.732 | **0.083** | 0.705 |
| **Lower 95% CI of mean** | 0.078 | 0.712 | 0.079 | 0.703 | 0.080 | 0.676 |
| **Upper 95% CI of mean** | 0.083 | 0.756 | 0.085 | 0.761 | 0.085 | 0.735 |

**Tab. 3.** *Relationship between epidermal thickness in the first 24 hours of life and post-conceptional age*

| | Forearm | Abdomen | Thigh |
|---|---|---|---|
| ***R*** | 0.39 | 0.43 | 0.35 |
| ***p*** | 0.004 | 0.002 | 0.013 |

to the thigh and forearm. In HF-US measurements performed on the skin of the thigh and forearm, the differences were statistically insignificant (Tab. 4). The morphology of the dermis was found to be homogeneous throughout the entire dermal thickness in all examined sites, without a division into layers characterised by noticeable differences in echogenicity.

## Subcutaneous tissue

The ultrasound images of the subcutaneous tissue revealed oedema in all examined sites (Fig. 5). The presence of oedema often hindered thickness measurements of the subcutaneous tissue, as the lower tissue boundary extended beyond the penetration range of the probe. Consequently, this parameter was excluded from analysis. The examination results showed that the echogenicity of the subcutaneous tissue was significantly lower in the abdominal area as compared to the forearm and thigh. The differences in echogenicity between the forearm and thigh were statistically insignificant (Tab. 4). The severity of subcutaneous oedema varied depending on the body site and also across the newborns.

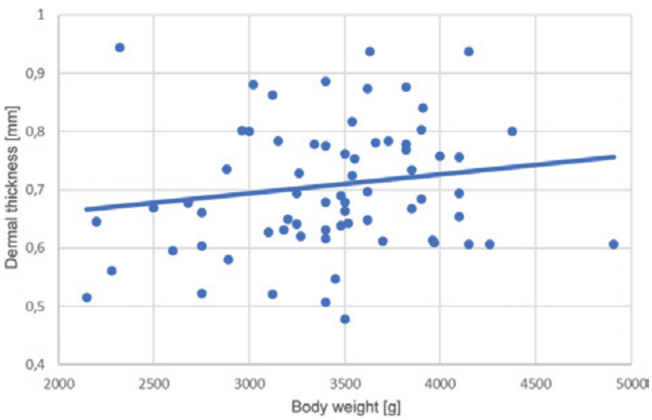


**Fig. 4.** *Relationship between dermal thickness and body weight on the thigh*

Since there are no literature reports describing measurement methods and tools for the evaluation of the severity of oedema, for the purpose of the study, oedema was assessed on the basis of thickness, surface area, and echogenicity. Oedema on the thigh and abdomen was found to be more severe than on the forearm in all neonates included in the study (greater thickness and surface area, lower echogenicity). Newborns with higher birth weights had a higher percentage of dark pixels in the range of 0–80 on the forearm and thigh ($R = 0.33$, $p = 0.02$; and $R = 0.33$, $p = 0.03$ for the forearm and thigh, respectively). The severity of oedema was higher, as a greater percentage of dark pixels indicates a higher level of tissue hydration.

Neither the sex nor the general condition of the newborns had a significant effect on the degree of oedema.

## Conclusions

1. Depending on the body site examined, the mean epidermal thickness ranged from 0.081 to 0.083 mm.
2. The mean values of dermal thickness ranged between 0.679 and 0.722 mm.
3. Differences in epidermal and dermal thickness depending on the examined body site were not statistically significant.
4. The newborns with a higher body weight were characterised by a thicker epidermis in all body sites examined.
5. The lowest echogenicity of the dermis and subcutaneous tissue was found in the abdominal region.
6. Subcutaneous oedema was detected in all newborns studied.

## Discussion

The aim of the study was to determine the usefulness of high-frequency ultrasound imaging as a tool to assess the baby's skin after birth, and to analyse differences in ultrasound features of the skin in a group of newborns during the first 24 hours of life.

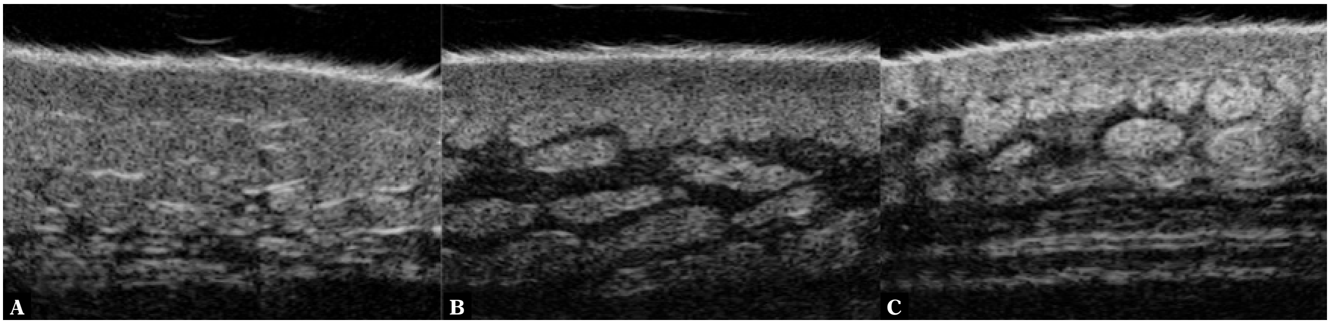


**Fig. 5.** *Ultrasound image (DermaMed unit with a 48 MHz probe) of subcutaneous oedema in a newborn in the first 24 hours of life.* **A.** *Forearm* **B.** *Abdomen* **C.** *Thigh*

Neonatal epidermis has a very thin structure, so epidermal measurements in newborns require extreme precision and extensive experience from the examiner, and may be associated with a risk of errors[5]. The results obtained by the authors of the study reveal a clear difference in epidermal thickness between newborns and other age groups reported in the literature. In adults, the epidermis is 0.132 mm thick on the inner forearm, and 0.147 mm on the outer forearm[5]. A study by the authors of this paper showed that the thickness of the epidermis in newborns on the outer side of the forearm was 0.081 mm. The wide confidence interval (95% CI) determined for this parameter in all areas examined in this case is probably an effect of long-term skin exposure to the aquatic (intrauterine) environment. Ultrasound images of neonatal skin are distinct for a large number of reflections at the gel/epidermis interface, which impairs the accuracy of measurement. A physiological phenomenon occurring during the period of skin adaptation after birth is skin exfoliation. Exfoliated epidermal cells may cause the accumulation of air bubbles directly at the interface between the epidermis and the gel layer, which makes it more difficult to determine sharp boundaries that are measured and then analysed.

A positive correlation found in the present study between birth weight and thickness of different skin layers (both epidermis and dermis) is different from the findings of other authors. Vitral *et al*.[6] found no such relationship, but demonstrated that a thicker epidermis and thinner dermis are characteristic features of babies born later in pregnancy.

**Tab. 4.** *Differences in the echogenicity of the dermis and subcutaneous tissue between the three examined sites*

| **Dermis (echogenicity)** | |
|---|---|
| **Kruskal-Wallis test, *p* <0.0001** | |
| Dunn's Multiple Comparison Test | *p* |
| forearm vs abdomen | <0.05 |
| forearm vs thigh | NS |
| abdomen vs thigh | <0.05 |
| **Subcutaneous tissue (echogenicity)** | |
| **Kruskal-Wallis test, *p* <0.0001** | |
| Dunn's Multiple Comparison Test | *p* |
| forearm vs abdomen | <0.05 |
| forearm vs thigh | NS |
| abdomen vs thigh | <0.05 |

Consequently, both parameters can be used to assess the maturity of newborns after birth regardless of intrauterine foetal growth disorders.

There are no other reports on newborns in the literature, so drawing final conclusions requires further studies in a larger group of children, and with appropriate objectification of measurements and study methods.

Dermal thickness analysis showed no sex-associated differences in any areas examined. Van Mulder *et al*.[1], evaluating the dermis in the adult population, found that typical male dermis was significantly thicker than female dermis. Comparing the findings of the above study and the results obtained by the authors of this paper, it can be concluded that skin thickness at birth does not depend on the baby's sex. Nevertheless, internal factors (genetically determined, such as the effects of hormones in the maturation process) induce the differentiation and development of skin layers, contributing to the subsequent sex-associated variability.

No differences in epidermal and dermal thickness were found in the studied newborns across the examined body sites. However, differences in the thickness of different skin layers depending on body location in the adult population observed by other authors may stem from skin maturation processes and skin response to environmental factors[5].

The lowest echogenicity of the dermis was found in the abdominal region. This shows that the location has less collagen fibres reflecting ultrasound waves compared to the thigh and forearm. According to other authors, echogenicity of the dermis increases with age. The lowest echogenicity is found in newborns, and it begins to rise in children aged a few months, increasing until the old age[7,8].

Ultrasound images obtained in the present study revealed homogeneous echogenicity of dermal morphology across the entire width of the dermis. This is a significant difference compared to the findings reported by other authors. A clear division into the upper and lower layers of the dermis, which vary significantly in their echogenicity, is usually highlighted. The upper layer is hypoechogenic, while the lower, corresponding anatomically to the reticular layer, rich in collagen fibres, is hyperechogenic[4,7]. The homogeneous structure of skin morphology in newborns is probably due to the immaturity of skin layers and a difference in anatomical structure. However, further studies are needed to confirm this hypothesis.

Based on the findings, the authors of the study concluded that the observed heterogeneous morphology of the subcutaneous tissue is due to oedema. However, there are no publications addressing this topic, either based on HF-US or other skin imaging tools. The ultrasound features of tissue oedema include a "cobblestone/pavement" pattern, which corresponds to the phenomenon observed by the authors (Fig. 5). Based on the study findings, it can be concluded that subcutaneous tissue oedema is a physiological phenomenon occurring after birth, as it was found in all newborns in all skin sites examined. Variability observed in the degree of oedema between newborns and body sites, as well as its underlying causes, require more in-depth studies.

Another point of note is that subepidermal loss echogenicity band (SLEB) was not observed in any body sites examined in the newborns during the first 24 hours of life. SLEB has been reported by other authors, both in adults and in cases involving skin pathologies, such as atopic dermatitis[2]. This corroborates to some extent the assumption that SLEB is an effect of external factors acting on the skin, e.g. ultraviolet radiation, skin aging or skin damage by pathogenic factors[9,10].

## Conclusions

High-frequency ultrasound imaging may become a useful method for skin assessment in newborns, complementing existing diagnostic techniques for monitoring pathologically altered skin. Technologically advanced, precise ultrasound probes designed for skin imaging enable the dissemination of the technique and its applications in clinical practice. It is necessary to develop uniform standards for the imaging of healthy skin, particularly in newborns and infants, so that HF-US can be used for the assessment of skin pathologies.

### Conflict of interest

*The Authors do not declare any financial or personal links with other persons or organisations that might adversely affect the content of the publication or claim any right to the publication.*

## References


1. Van Mulder TJ, de Koeijer M, Theeten H, Willems D, Van Damme P, Demolder M *et al*.: High frequency ultrasound to assess skin thickness in healthy adults. Vaccine 2017; 35: 1810–1815.
2. Visscher M, Adam R, Brink S, Odio M: Newborn infant skin: physiology, development and care. Clin Dermatol 2015; 33: 271–280.
3. Habeshian KA, Kirkorian AY: Common neonatal skin lesions: melanocytic nevi, pigment alterations, and nonmelanocytic nevi. Pediatr Ann 2019; 48: e23–e29.
4. Mlosek RK, Malinowska S: Ultrasound image of the skin, apparatus and imaging basics. J Ultrason 2013; 13: 212–221.
5. Mlosek RK, Malinowska S, Stępień A, Czekaj K, Dąbrowska A: Changes in the high frequency skin ultrasound associated with aging. Ultrasonogr 2011; 47: 22–27.
6. Vitral GLN, Aguiar RAPL, de Souza IMF, Rego MAS, Guimarães RN, Reis ZSN: Skin thickness as a potential marker of gestational age at birth despite different fetal growth profiles: a feasibility study. PLoS One 2018; 13: e0196542.
7. Barcaui E, Carvalho AC, Piñeiro-Maceira J, Baracui CB, Moraes H: Study of the skin anatomy with high-frequency (22 MHz) ultrasonography and histological correlation. Radiol Bras 2015; 48: 324–329.
8. Polańska A, Dańczak-Pazdrowska A, Jałowska M, Żaba R, Adamski Z: Current applications of high-frequency ultrasonography in dermatology. Postepy Dermatol Alergol 2017; 34: 535–542.
9. Jasaitiene D, Valiukeviciene S, Linkeviciute G, Raisutis R, Jasiuniene E, Kazys R: Principles of high-frequency ultrasonography for investigation of skin pathology. J Eur Acad Dermatol Venereol 2011; 25: 375–382.
10. Crisan D, Lupsor M, Boca A, Crisan M, Badea R: Ultrasonographic assessment of skin structure according to age. Indian J Dermatol Venereol Leprol 2012; 78: 519.