Photon transport in biological tissue can be modeled as the diffusion approximation of an RTE (radiation transfer equation) because the skin is a scattered dominated medium.\cite{2} The RTE was expressed as Helmholtz equation, shown in Eq.1, in COMSOL and an LED light source was applied on the boundary which equation is shown in Eq.2. Continuity was used as boundary conditions where the skin and blood vessels are in contact.

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\nabla \cdot (-c \nabla u) + au = f \quad \text{(Eq. 1)}
\]

\[
-n \cdot (-c \nabla u) = g - qu \quad \text{(Eq. 2)}
\]

Schematics of SolidWorks model of the skin including dermis, epidermis and subcutaneous dermis as well as the veins with different diameters and subcutaneous veins with different diameters.

### Computational Methods

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### Results

The COMSOL 3-D skin model showed clear distinction between the skin and subcutaneous veins where optical properties are significantly different as shown in Figure 2. Contrast between the tissue and blood vessels, shown in Figure 3, depends on wavelength of the light source and size and depth of the veins. The contrast was enhanced at the wavelength of 880 nm (Figure 4) and for larger veins (Figure 5), and reduced for deeper veins (Figure 6).

![Image of vein visualization system](image_url)

Figure 2. Light absorption by blood at different skin depths

![Image of light intensity](image_url)

Figure 3. Light intensity determines the contrast

![Image of light absorption](image_url)

Figure 4. Light absorption at different Wavelengths of light sources

![Image of light absorption at different vein diameters](image_url)

Figure 5. Light absorption at different vein diameters

![Image of light absorption at different depth of the veins](image_url)

Figure 6. Light Absorption at different depth of the veins

### Conclusions

The 3-D COMSOL model effectively shows the contrast of the veins from the surrounding tissue. The advantage of this model is that the topology of vasculatures can be modified easily using 3-D CAD modeling software or a scanner. This model can effectively be used to advance the design and practices of vein visualization devices for projection and clinical assessment of dermal blood vessels. Further research will compound a more complex 3-D geometry, location variation of the light source as well as the skin variation such as melamine.

### References


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**Table 1. Absorption and scattering coefficients of skin and whole blood**\cite{1}

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Skin</th>
<th>Whole Blood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\mu_a) (cm(^{-1}))</td>
<td>(\mu'_s) (cm(^{-1}))</td>
</tr>
<tr>
<td>650</td>
<td>8.9</td>
<td>2.73</td>
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<td>760</td>
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<tr>
<td>880</td>
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