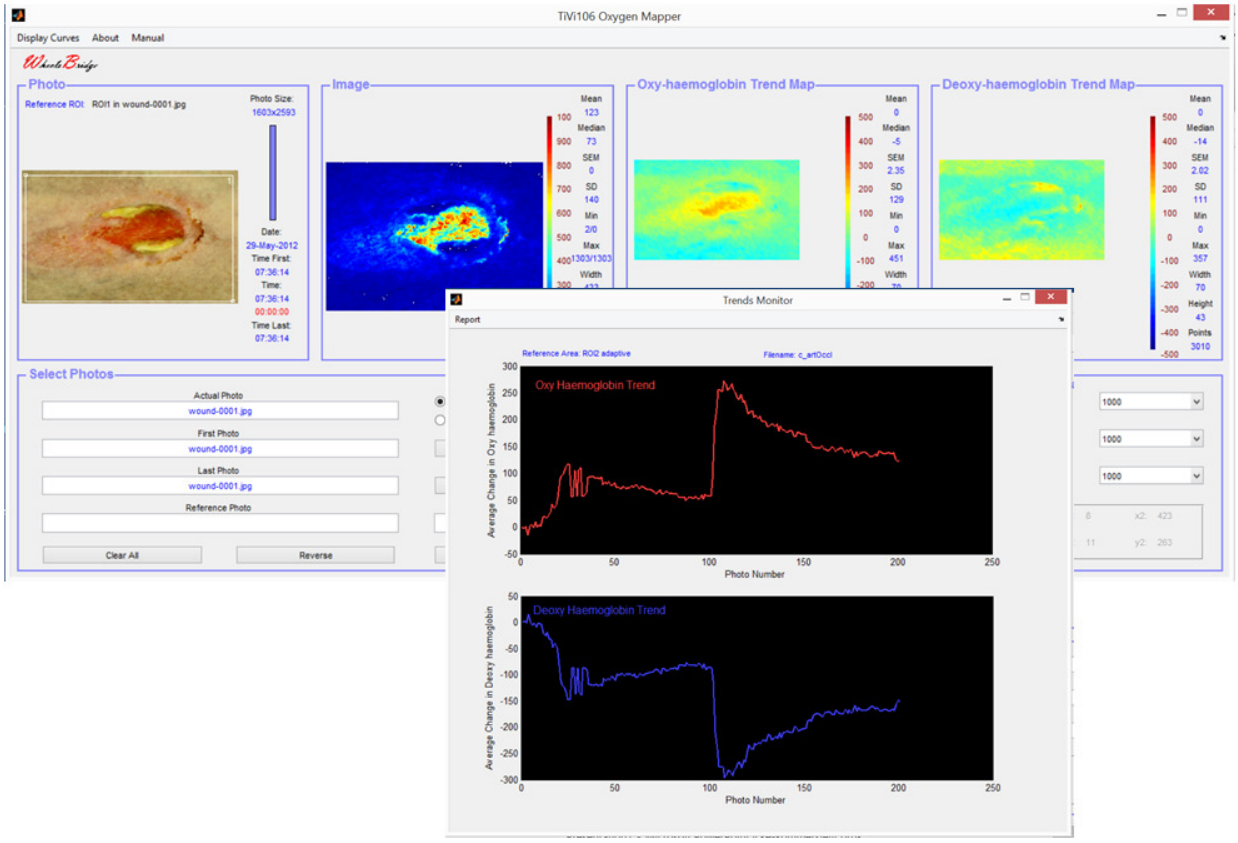
WheelsBridge



Oxygen Mapper TiVi106
User Manual

User Manual 1.1
Version 1.1
March 2015

PIONEERS IN TISSUE VIABILITY IMAGING

Dear Valued Customer!

Welcome to the WheelsBridge TiVi106 Oxygen Mapper toolbox intended for automatic and user-independent analysis of alterations and trends in tissue oxy- and deoxy-haemoglobin.

The WheelsBridge TiVi106 Oxygen Mapper toolbox utilizes a highly sensitive digital camera with polarization filters making it possible to suppress surface reflections from the skin. The versatile system software – based on the MATLAB® high performance language for technical computing – allows for rapid and easy capturing and analysis of images. Among the many useful features of the TiVi106 Oxygen Mapper software the following are of particular interest:

- *Automatic capturing of photos in cross-polarized mode.*
- *Lateral resolution approximately 5 micro-meters per pixel when using the TiViMagnifier (optional).*
- *Generates trend maps of tissue oxy- and deoxy-haemoglobin.*
- *Automatically calculates trend curves from a stack of photos.*
- *Oxy- and deoxy-haemoglobin trend maps and curves are constructed using a baseline region of interest or adjacent regions of interest as reference.*
- *All data generated can be exported to ASCII-format spread sheets.*
- *Integrated Report Generator facilitates print out of main results.*

We are convinced that the TiVi106 Oxygen Mapper will be a productive tool in the validation of the tissue repair processes ,in assessment of the healing wound and many other applications.

Thank you for choosing the WheelsBridge TiVi106 Oxygen Mapper.

WheelsBridge AB

1. INTRODUCTION

The haemoglobin molecules in the red blood cells are responsible for transportation of oxygen from the lungs to the tissue. Light absorption properties of the haemoglobin molecules are dependent on the oxygen saturation status which can be assessed by analysis of diffused back-scattered light in the visible region. If the amount of light absorption in tissue within the red and green wavelength bands is analyzed, trend maps of the relative concentration of oxy- and deoxy-haemoglobin can be constructed and displayed.

From a technical point of view alterations in local concentration of oxy- and deoxy-haemoglobin can be assessed by the use of polarization spectroscopy imaging provided by the *Tissue Viability Imaging system TiVi700* operating in cross-polarized mode.

The wave-length-dependent local alteration in Optical Density of diffusely backscattered light (ΔOD) is proportional to the sum of the products of the chromophore's extinction coefficient (ε) and the alterations in concentration of the different chromophores (ΔC). Given that – in addition to different chromophores in the basic tissue matrix - the most important dynamically changing chromophores in tissue are the oxy- and deoxy-haemoglobin molecules, the following equations can be set up for the red and the green wavelength bands:

$$\Delta OD(red) \sim \varepsilon_{oh}(red) * \Delta C_{oh} + \varepsilon_{doh}(red) * \Delta C_{doh} + \varepsilon_{tissue}(red) * \Delta C_{tissue}$$

$$\Delta OD(green) \sim \varepsilon_{oh}(green) * \Delta C_{oh} + \varepsilon_{doh}(green) * \Delta C_{doh} + \varepsilon_{tissue}(green) * \Delta C_{tissue}$$

where $\varepsilon_{oh,}$ ε_{doh} and ε_{tissue} represent the extinction coefficients for oxy-haemoglobin, deoxy-haemoglobin and tissue respectively,

and

$\Delta C_{oh,}$ ΔC_{doh} and ΔC_{tissue} represent the changes in concentration (from a reference point in time or reference tissue area) respectively.

Under the assumption that the tissue matrix does not change in the short term perspective, ΔC_{tissue} can be set to zero and the equation system transforms into:

$$\Delta OD(red) \sim \varepsilon_{oh}(red) * \Delta C_{oh} + \varepsilon_{doh}(red) * \Delta C_{doh}$$

$$\Delta OD(green) \sim \varepsilon_{oh}(green) * \Delta C_{oh} + \varepsilon_{doh}(green) * \Delta C_{doh}$$

This new equation system is composed of two equations with two unknown variables (ΔC_{oh} and ΔC_{doh}) and can therefore be solved (ΔC_{oh} and ΔC_{doh} can be calculated) based on the extinction coefficient values and average path-lengths tabulated in the literature, the known sensitivity of the camera and spectral density of the illuminating light, and the measured difference in OD in the back-scattered light.

In practice the reference values can be obtained in one of three different ways.

1. One of the photos in a stack of photos can be used as the reference photo. The actual reference area is defined by the user-drawn region of interest in this photo. Only a single region of interest is needed in this case and the region of interest in the reference photo constitutes the basis for calculating the reference value. The benefit of this alternative is that the same skin site is used for reference and measurement. The drawback is that the reference value and the actual measurement value may be calculated from photos captured at different points in time.

2. One of the photos in a stack of photos can be used as the reference photo. The actual measurement area is defined by the user-drawn region of interest in this photo. A second region of interest defines the reference area. Two regions of interest are required in this case and the second region of interest in the reference photo constitutes the basis for calculating the reference value. The benefit of this alternative is that different skin sites can be used for reference and measurement respectively. The drawback is that the reference value and the actual measurement value are still calculated from photos captured at different points in time.

3. In an alternative arrangement the reference area is continuously updated and based on a region of interest in the same photo as the measurement region of interest. The actual measurement area is defined by the region of interest drawn by the user in this photo. A second region of interest defines the reference area. Two regions of interest are required in this case. The benefit of this alternative is that different skin sites can be used for reference and measurement and that the actual reference area is calculated from the same photo as the measurement area (i.e. based on values captured at the same point in time). The drawback may be that the reference value and the actual measurement value are calculated from two separate sites on the skin.

The intended use of the *TiVi106 Oxygen Mapper* is to analyse changes in concentration of oxy- and deoxy-haemoglobin molecules in skin or other tissue in experimental and research applications. It is not yet approved for the diagnosis and treatment of disease.

2. OPERATING PRINCIPLE

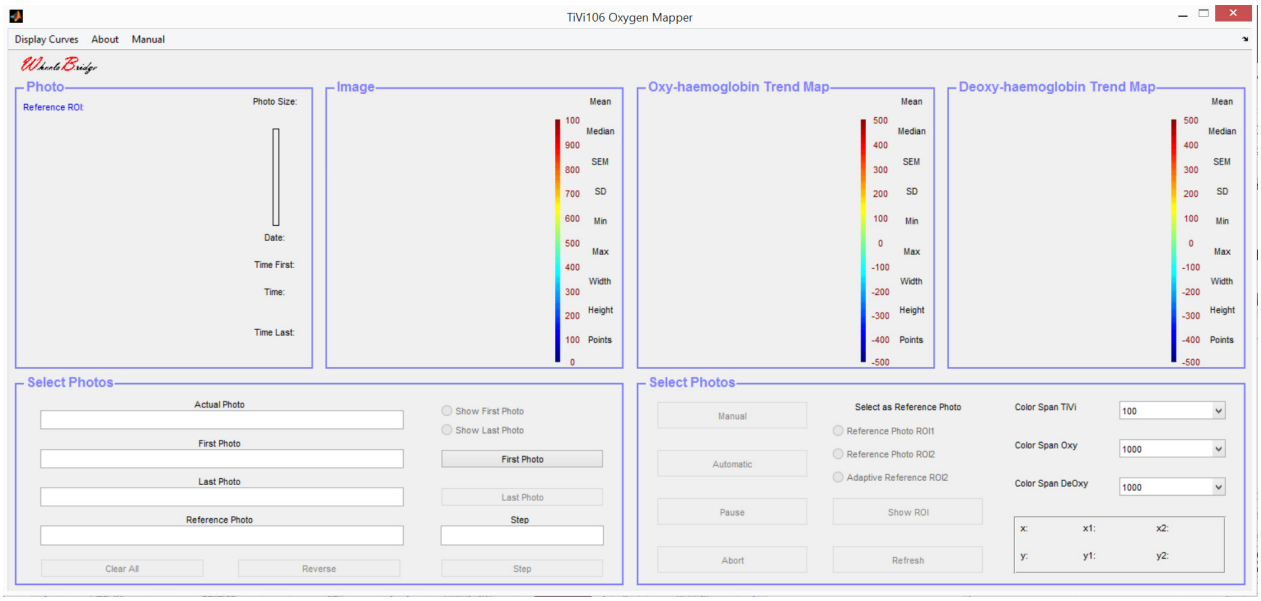
After uploading as single or a sequence of photos, a region of interest is drawn in the photo to define the measurement area (white color boundaries). The relative changes in oxy- and deoxy-haemoblogin within the region of interest are mapped and displayed. If only a single region of interest is employed, the reference oxy- and deoxy-haemoglobin maps are calculated as the average oxy- and deoxy- hamoglobin values within the region of interest. The oxy- and deoxy-haemoglobin maps therefore display spatial variations around these average values with the azure color as the zero deviation indicator color while pixels with values higher than the average value are displayed in colors towards red and pixels with values lower than the average value are displayed in colors towards blue. If as sequence of photos is uploaded, the reference map is always based on the average oxy- and deoxy-haemoglobin values within the actually displayed photo after the **Reference Photo ROI1** radio-button is clicked.

If a second region of interest (green color boundaries) is drawn, this region of interest defines the reference area. In case the **Reference Photo ROI2** radio-button is selected, the reference map is calculated based on the average values of the actually displayed photo and the associated reference map is used in all the photos in the sequence. In case the **Adaptive Reference ROI2** is selected, the reference map is continuously updated based on values within the region of interest in the actually displayed photo while scanning through the entire sequence of photo. When all photos have been scanned through clicking **Display Curves** in the pull-don menu opens a new window that displays changes (in arbitrary units) of the average oxy- and deoxy-haemoglobin values within the measurement region of interest with reference to the selected reference values as selected by the **Select As Reference** radio-buttons.

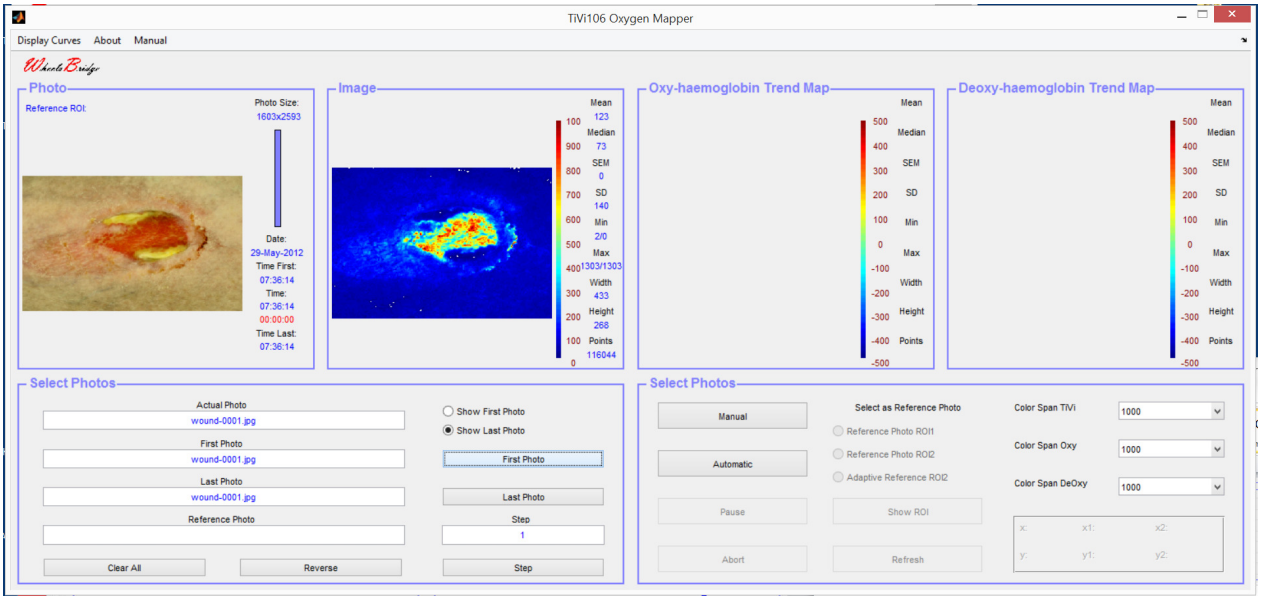
3. GETTING STARTED

The basic features of the *TiVi106 Oxygen Mapper* are probably best explained by way of an example. In the following example it is assumed that the photos *wound-0001.jpg* and *c_artOccl-0001.jpg – c_artOccl-0201.jpg* have been captured by a TiVi camera system and stored in the *TiVi106 demonstration* folder. These photos display a healing wound and a stack of photos during arterial occlusion at the ankle level followed by the post-occlusive hyperaemia respectively.

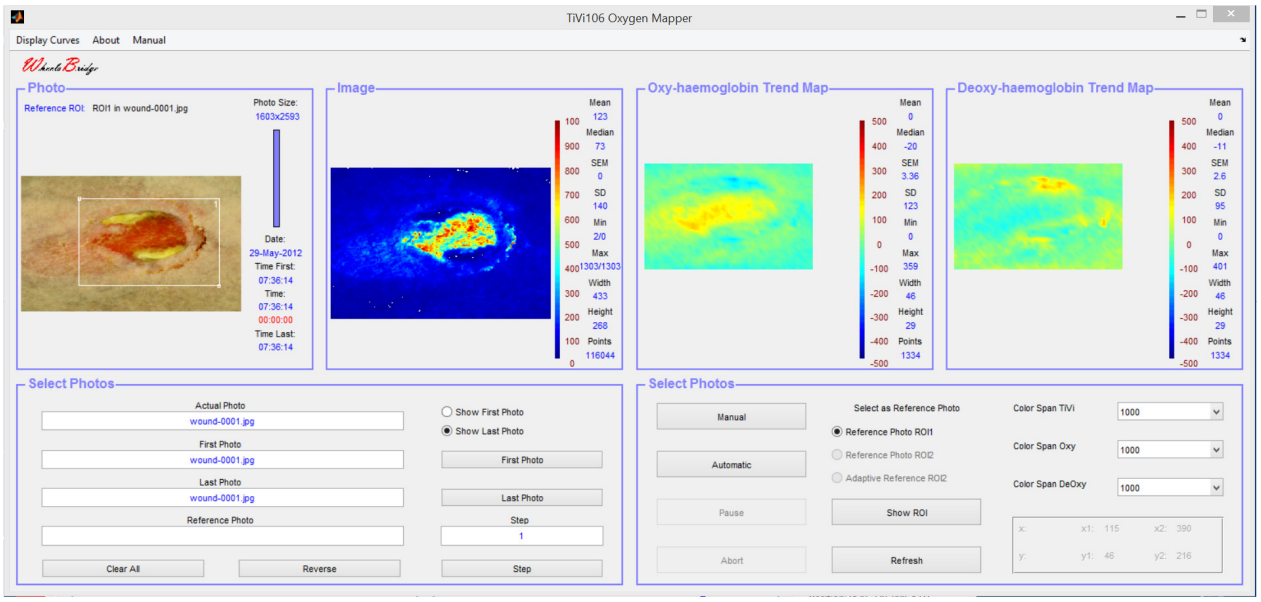
1. Open the *TiVi106 Oxygen Mapper* toolbox from the **Toolbox** pull-down menu in the *TiVi700 Analyzer* window.



2. Click the **First Photo** button and navigate to the *TiVi106demonstration* folder. Double-click the *wound-0001.jpg* file. This photo will now be uploaded from the disk and displayed together with the corresponding TiVi-image (map of red blood cell concentration).

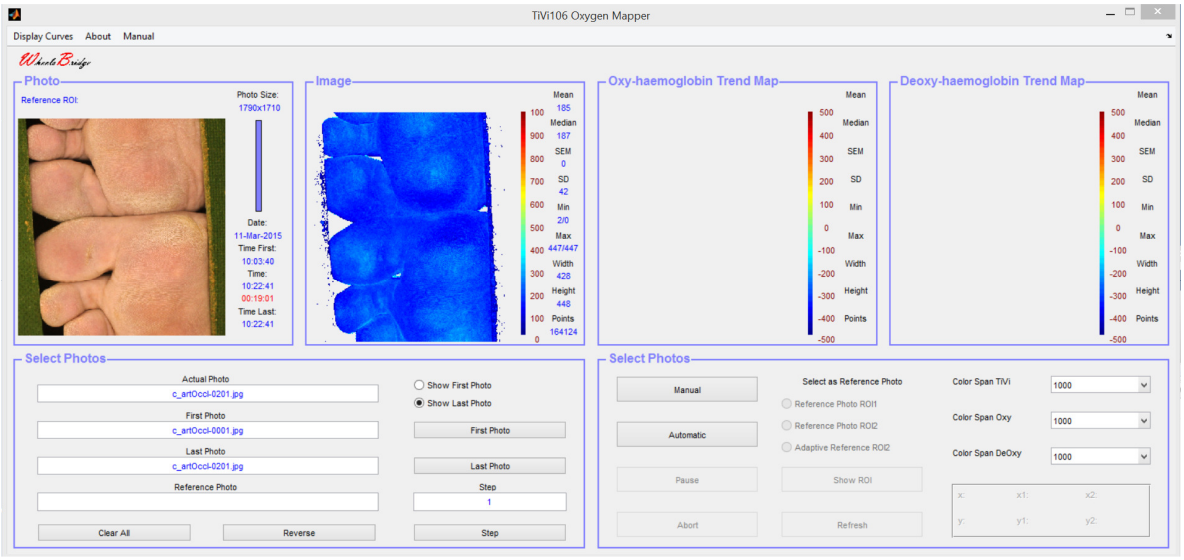


3. Draw a region of interest around the wound area in the photo. The relative oxy- and deoxy-haemoglobin maps will now be displayed. The references maps are calculated based on the average value of the oxy- and dexyhaemoglobin concentrations inside the region of interest and the actual relative oxy- and deoxy-haemoglobin maps are calculated with respect to these reference maps.

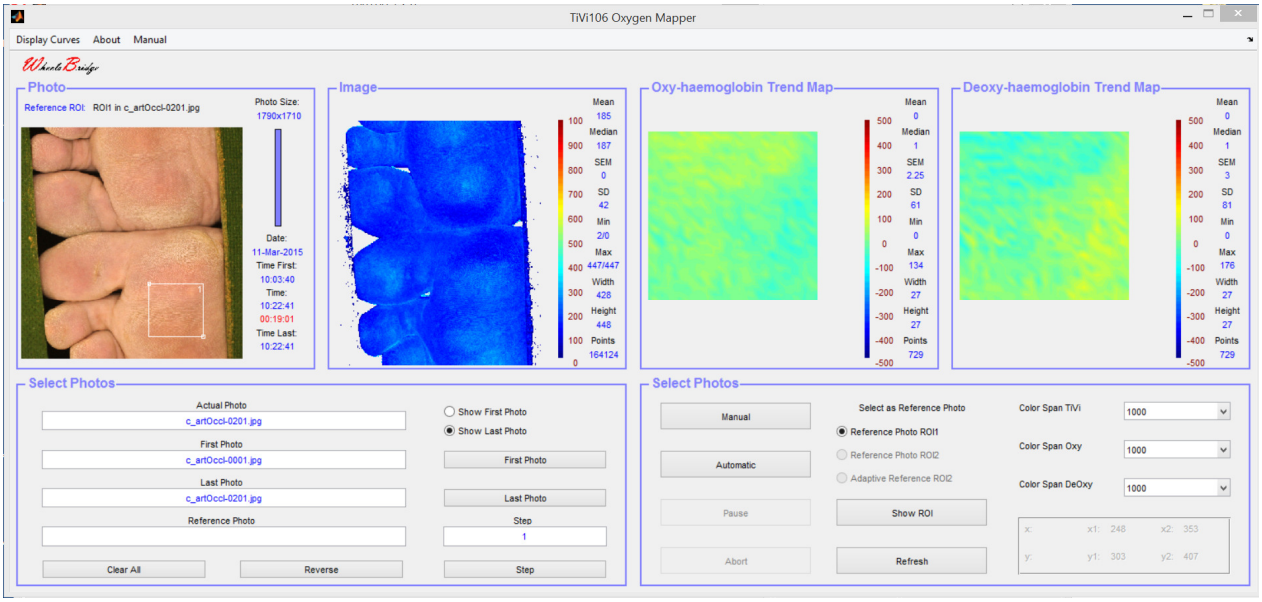


4. Click the **Clear All** button to reset the *TiVi106 Oxygen Mapper* window.

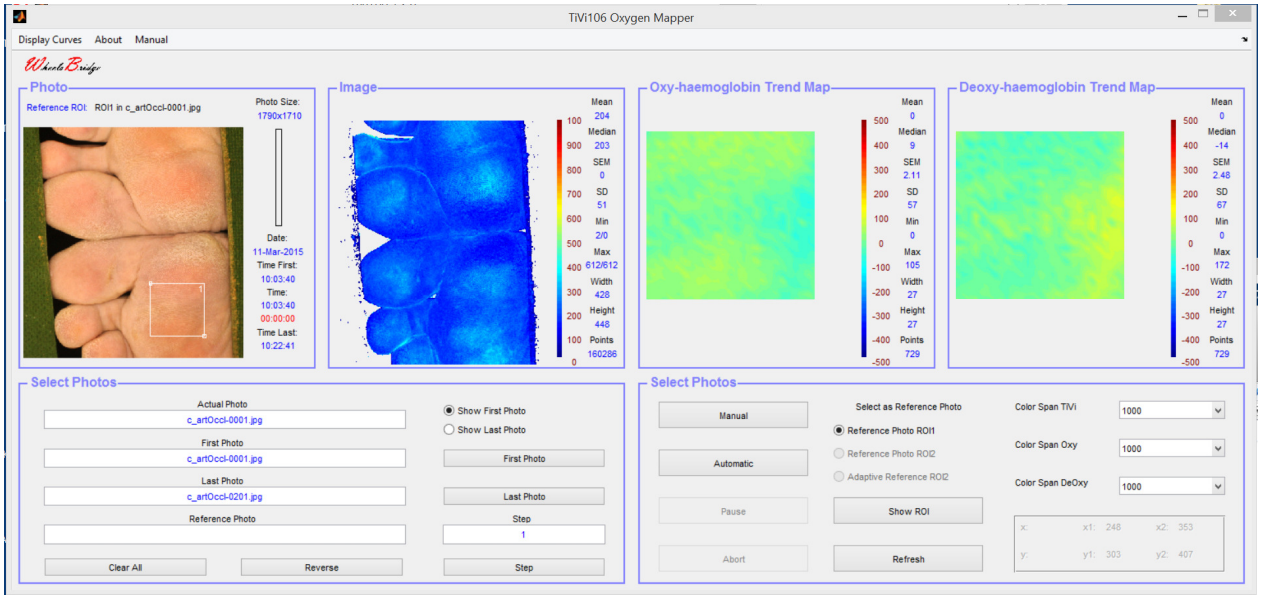
5. Click the **First Photo** button and navigate to the *TiVi106demonstration* folder. Double-click the *c_artOccl-0001.jpg* file. The last photo in the actual sequence will now be uploaded and displayed.



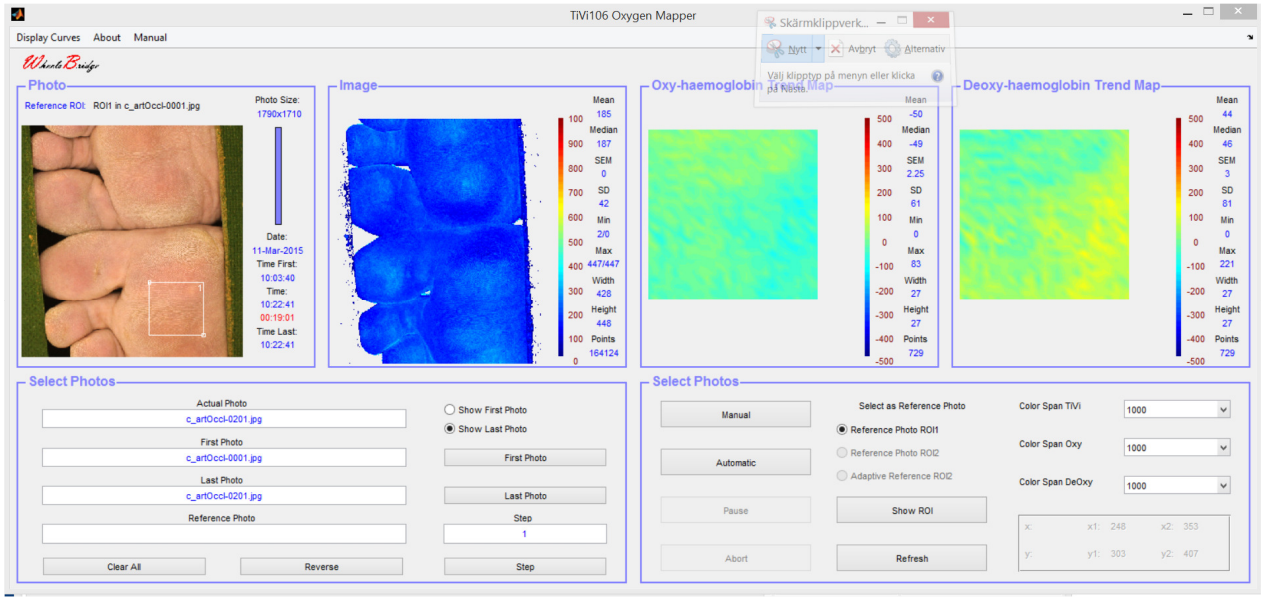
6. Draw a region of interest in the lower part of the photo.



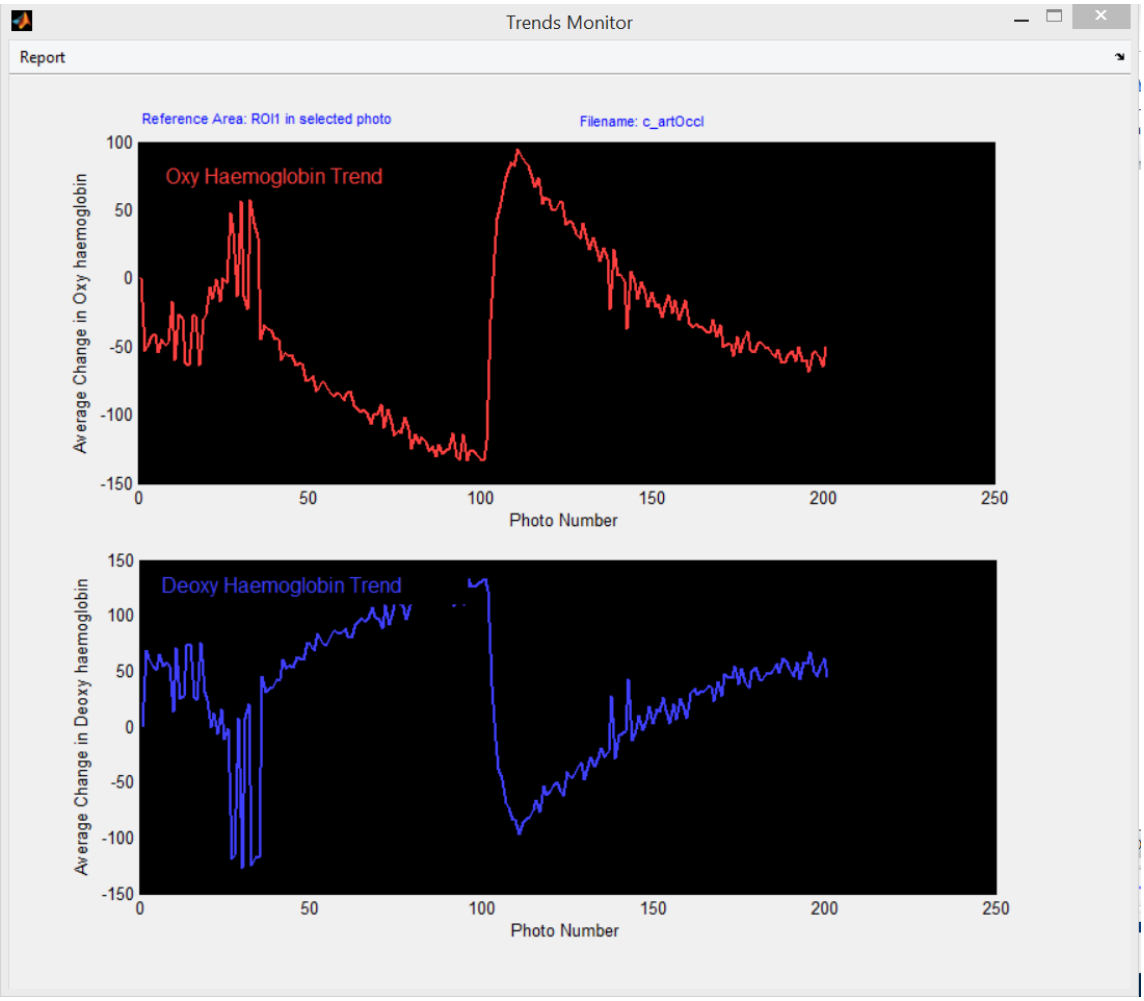
7. The reference area is now calculated as the average oxy- and deoxy hamoglobin concentration values within the actual region of interest and corresponding oxy-and deoxy-haemoglobin maps are displayed. To change the reference area to be calculated from the region of interest in the first photo click the **Show First Photo** radio-button and then click the Reference **Photo ROI1** button.



8. Click the **Automatic** button to scan through the photos in the sequence (and calculate the corresponding average oxy- and deoxy haemoglobin concentration changes).

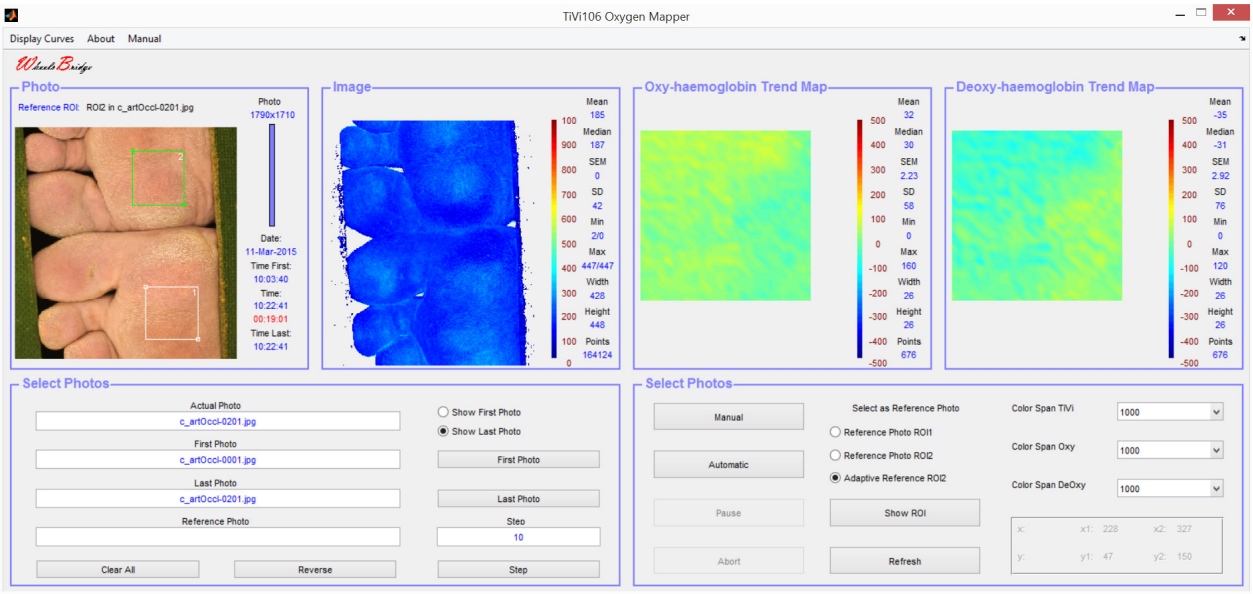


9. Select **Display Curves** in the pull-down menu to display the average changes in oxy- and deoxy-haemoglobin values within the (white) measurement region of interest (with respect to the average values within the same region of interest in the first photo in the sequence) in a separate window.



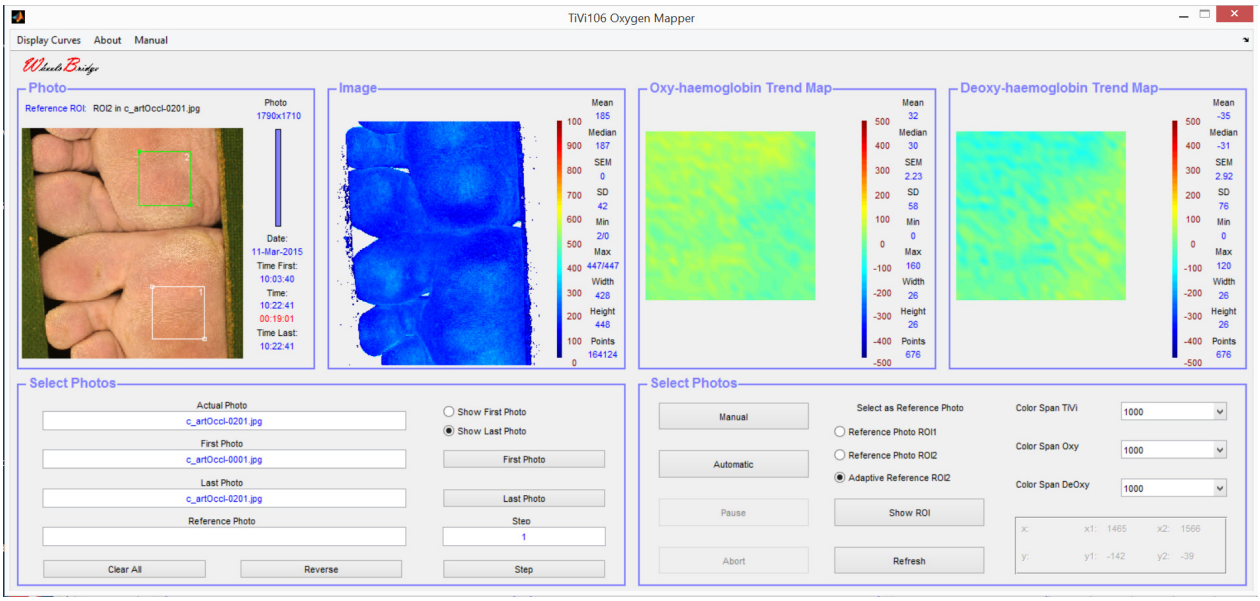
10. At photo number 25 a pressure cuff around the ankle was inflated to above systolic pressure. At this point in time the oxy-haemoglobin concentration starts to decrease while the deoxy-haemoglobin concentration starts to increase. At photo number 100 the cuff is deflated and the reactive hypeaemia phase commences. The oxy-heamoglobin concentration increases steeply as oxygenated blood enters the tissue and is thereafter successively reduced. The deoxy-haemoglobin curve displays the inverse pattern.

11. Click the **Refresh** button to delete the regions of interest and draw two new regions of interest – one in each foot.

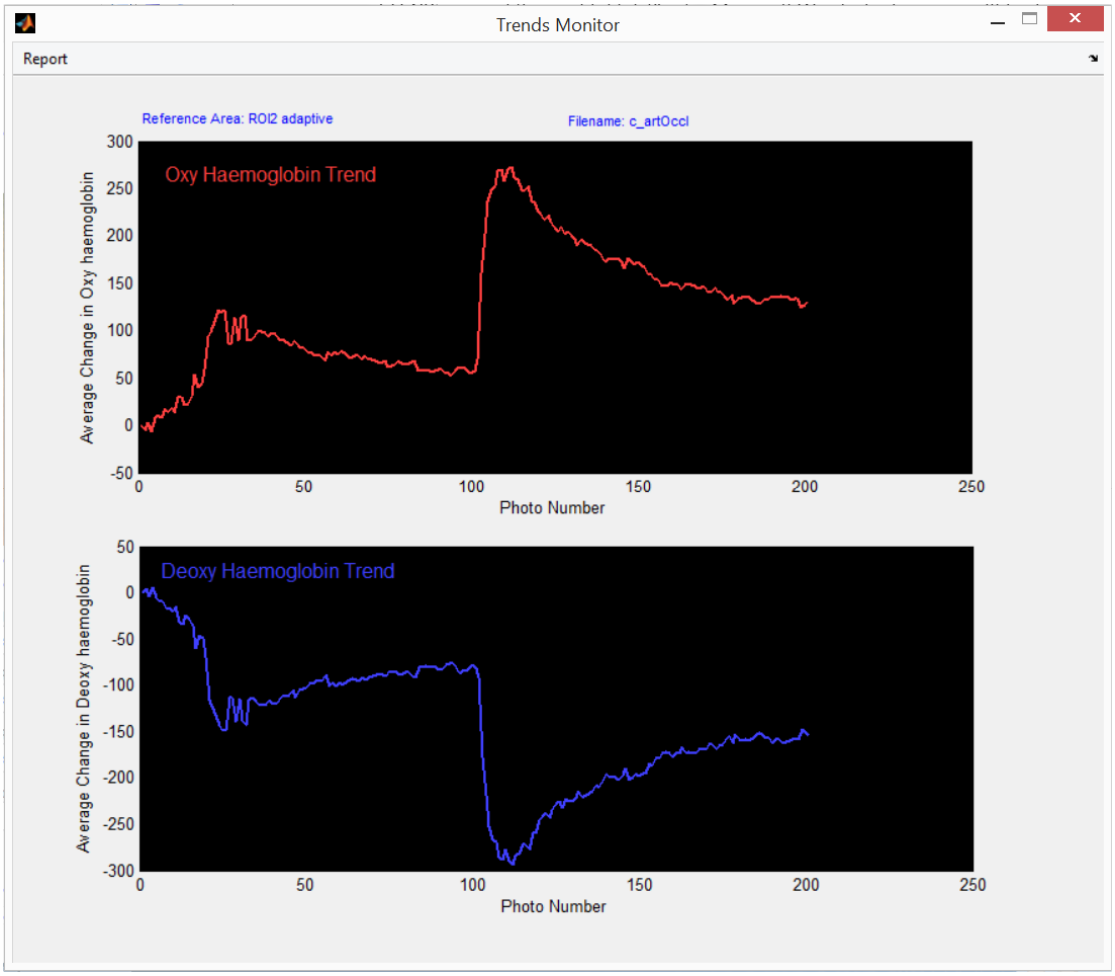


12. Note that the **Adaptive Reference ROI2** radio-button is automatically checked indicating that the system will now use the values within the white region of interest as measurement values and values within the green region of interest as reference values in each photo in the sequence.

13. Click the **Automatic** button to scan through the photos in the sequence.



14. Select **Display Curves** in the pull-down menu to display the curves in a separate window. Note the movement artefacts in the measurement curve are balanced out by the same artefacts in the reference curve (the latter based on region of interest values in the reference foot not subjected to arterial occlusion).



15. This completes the **GETTING STARTED** section.

4. DETAILED DESCRIPTION

The TiVi106 Oxygen Mapper main window

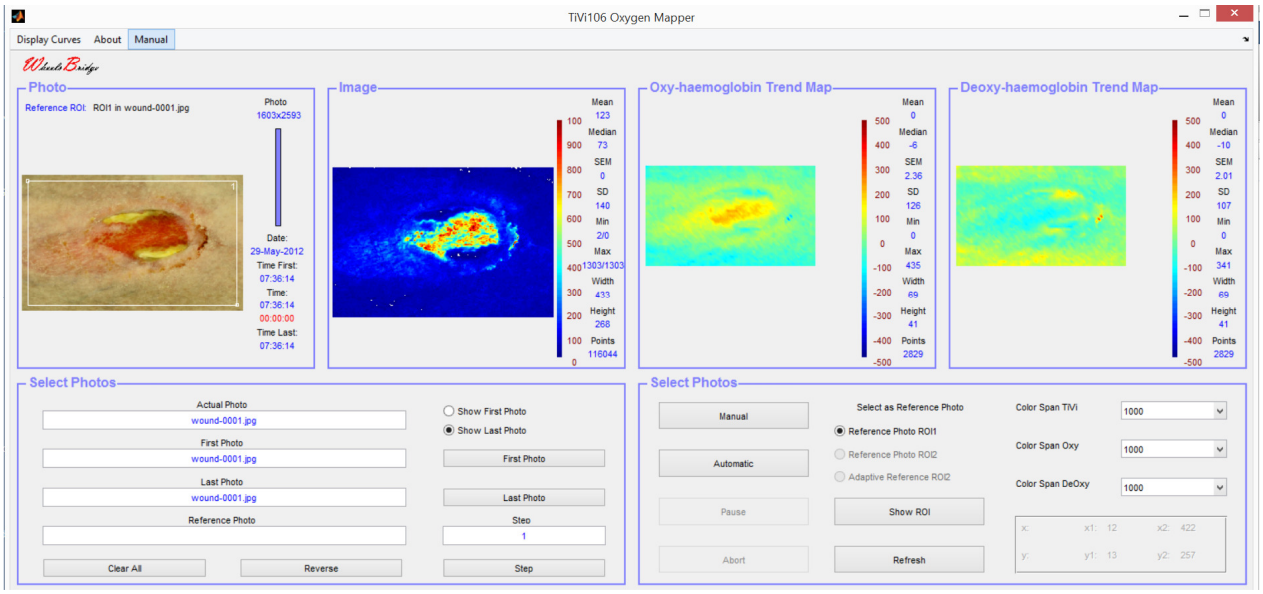


Photo Panel

1. Uploaded photo in which one or two regions of interest can be drawn. **ROI1** is always the measurement region of interest and **ROI2** is the reference region of interest.

2. **Reference ROI** text – displays the ROI selected and the name of the reference photo.

3. **Photo size** – indicates the size of the photo in pixels.

4. **Bargraph indicator** – displays the relative photo number.

5. **Date and Time** – displays the date of photo capture, time of first photo, time of actual photo, elapsed time from first photo and time of last photo.

Image Panel

1. TiVi-mage showing the local concentration of red blood cells corresponding to the displayed photo.

2. Color indicator scale.

3. Statistical image data.

Oxy-haemoglobin Trend Map

1. Relative Oxy-haemoglobin image corresponding to the **ROI1** image.
2. Color indicator scale.
3. Statistical Oxy-haemoglobin image data.

Deoxy-haemoglobin Trend Map

1. Relative Deoxy-haemoglobin image corresponding to the **ROI1** image.
2. Color indicator scale.
3. Statistical Deoxy-haemoglobin image data.

Select Photos Panel

1. **Actual Photo** edit box – to set and display the name of the actual photo.
2. **First Photo** edit box – displays the name of the first photo in the sequence selected.
3. **Last Photo** edit box – displays the name of the last photo in the sequence selected.
4. **Last Photo** edit box – displays the name of the last photo in the sequence selected.
5. **Reference Photo** edit box – displays the name of the reference photo selected.
6. **Show First Photo** radio-button - check to display the first photo.
7. **Show Last Photo** radio-button – check to display the last photo.
8. **First Photo** button – click to select the first photo in the sequence.
9. **Last Photo** button – click to select the last photo in the sequence.
10. **Step** edit box – to set and display the step in processed photos.
11. **Step** button – click to increment or decrement the step value.
12. **Reverse / Forward** button – click to set decrement or increment step.

13. **Clear All –** click to clear all settings and images**.**

Control Panel

1. **Manual** button – click o display the next photo and corresponding images in the sequence.

2. **Automatic** button – click to automatically scan through all photos in a sequence.

3. **Pause / Continue** button - click to pause or continue the automatic scan through procedure.

4. **Abort** button - click to halt the scan through procedure.

5. **Reference Photo ROI1** radio-button - click to use region of interest number 1 as reference. This radio-button is automatically enabled if only a single region of interest is drawn.

6. **Reference Photo ROI2** radio-button - click to use region of interest number 2 in the actual photo displayed as reference (while region of interest number one is the measurement region of interest).

7. **Adaptive Reference ROI2** radio-button - click to use region of interest number 2 adaptively in the presently displayed photo as reference (while region number one is the measurement region of interest). This radio-button is automatically enabled if two regions of interest are drawn.

8. **Color Span TiVi** pull-down menu – to select the color scale of the TiVi-image.

9. **Color Span Oxy** pull-down menu – to select the color scale of the oxy-haemoglobin image.

10. **Color Span DeOxy** pull-down menu – to select the color scale of the deoxy-haemoglobin image.

11. **x-y** panel – displays the coordinates of the actual region of interest.

Pull-down menus

1. **Display curves** pull-down menu – displays the oxy-haemoglobine and deoxy-haemoglobin curves in a separate window after all photo have been scanned through to calculate the individual values. This window includes a pull-down menu for printing out a one page **Report.**

2. **Export Data** pull-down menu **–** click to export the oxy-and deoxy-haemoglobin curves data to an *Excel* document.

3. **About** pull-down menu – displays information about the *TiVi106 Oxygen Mapper* toolbox.

4. **Manual** pull-down menu – displays the online *TiVi106 Oxygen Mapper* manual