# The use of Color Intensity Projections (CIPs) for visualizing pulmonary perfusion parameters with preservation of anatomy

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***Purpose:*** To show in a dynamic contrast enhancement study, that a color intensity projection (CIP) displays both perfusion parameters and anatomy in one comprehensive functional image.

***Materials and Method:*** Two patients were included: one with chronic thrombo-embolic pulmonary hypertension (CTEPH) and one with an obstruction of the left pulmonary artery. Patients were imaged with a Siemens 1.5T Sonata system (Siemens Medical Solutions, Erlangen, Germany) with a 6-element phased coil array placed on the thorax and 2 elements from the spine coil. Dynamic MR images (TR 2.02 sec; TE 0.68 sec; flip angle 20°; matrix 207 x 256; field of view: 400 x 400 mm; voxel size: 1.9 x 1.6 x 15.0 mm) were acquired with a three-dimensional spoiled gradient-echo sequence, and a GRAPPA acceleration factor of 2. Temporal resolution was 1.1s. Eight slices were obtained in the coronal plane during inspiratory breath hold. A contrast bolus of 0.2 ml/kg body weight Gadolinium (Magnevist® ) was administered via a cubital vein with a rate of 5 ml/s, followed by 20 mL of saline solution at the same rate.

From the signal intensity time curves, the maximum $SI_{max}$, the minimum $SI_{min}$, and the times to peak (TTP) with respect to the arterial input function (AIF) were calculated on a pixel-by-pixel basis. The CIP image [1] was constructed pixel by pixel as follows: the hue (wavelength of color) was determined by the time to peak, the saturation of color by the contrast enhancement ratio $(SI_{max}-SI_{min})/SI_{max}$ [2], and the brightness by $SI_{max}$.

***Results:*** Figure 1 shows the results from the embolism patient in one slice. Easy detection of heterogeneity within the lungs of this patient is possible because of the wide range of colors. Perfusion defects due to the emboli show up immediately as darker areas in the $SI_{max}$ image (1c), and in the resulting CIP (1d). Arteries and venes can be separated by different colors, and thus by different times to peak.

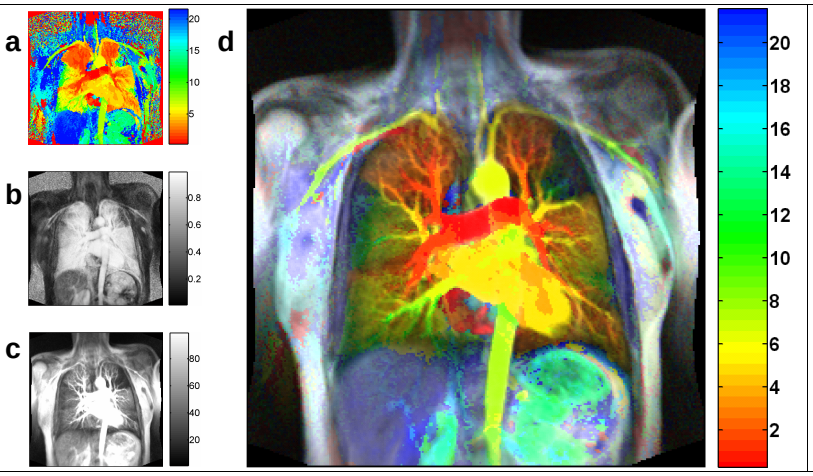


**Figure 1.** The Hue-Saturation-Brightness components and the CIP, illustrated in patient 1
**a)** The TTP image, where the color wavelength (hue) is determined by the TTP with respect to the TTP of the pulmonary artery. The scale is in seconds.
**b)** The contrast enhancement image, which determines the color saturation in the CIP.
**c)** The maximum signal intensity over time, which determines the signal intensity SI in the CIP.
**d)** The CIP combines TTP, contrast enhancement and maximum SI in one functional image.

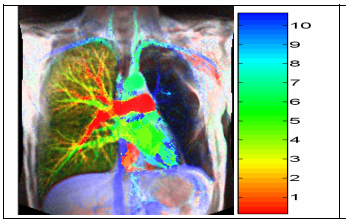


**Figure 2**. The CIP image for the time to peak (s), for patient 2.
In the right lung, arteries and venes are distinguishable by different colors, and thus different times to peak. The left lung is poorly perfused, reflected by the low maximal signal intensity. In the vessels that are perfused, the contrast arrives late (coded blue) due to the left pulmonary artery obstruction.

***Discussion:*** High saturation and brightness are typical for blood vessels, high saturation and average brightness are typical for normal lung parenchyma, and low saturation and brightness indicate poorly perfused regions. Thereby, more pulmonary anatomical and functional information is presented in a CIP, as compared to commonly used functional maps that present one single parameter. Presumably a CIP is helpful to interpret the information from many time phase images. The procedure is fully automatic and thus the radiologist does not need to do any manual segmentation. So far only the time to peak was displayed; the same procedure can be applied to any other functional parameter of pulmonary perfusion.

***Conclusion:*** The CIP is presented as one comprehensive functional image. A perfusion parameter is combined with anatomical information which is provided by the contrast enhancement ratio and the maximum signal intensity.

***References:*** [1] Cover KS et al., Color intensity projection of digitally subtracted angiography for the visualization of brain arteriovenous malformations. Neurosurgery, 2007. 60(3): p. 511-515.

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