Optical Flow Techniques with Peak Detection Method for Ciliary Beat Frequency Measurement

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ABSTRACT

The transport of mucous in the ciliary mucosa can be measured by observing ciliary movements. The conventional method for measuring ciliary beat frequency is to record with a high-speed digital video camera and then apply difference image analysis. We compared this method to the optical flow technique with peak detection analysis. We examined 50 human nasal mucosa samples using both techniques, and found that the accuracy of the optical flow technique was 90.15%, while that of the conventional method was 84.82%.

INTRODUCTION

The main purpose of the respiratory tract's mucociliary system is to eliminate inhaled particles through the propulsion of mucus. The overall propulsive effect depends on the arrangement of the cilia, their metachronal relationships, and the ciliary beat frequency (CBF).¹ Several methods have been developed to measure CBF, but most require very sophisticated devices. Recently, a simple method using a commercial high-speed video camera was introduced to capture images of ciliary movement. This method uses difference image analysis and a fast Fourier transformation algorithm for CBF measurement, but requires time-consuming manual calculations.² In this study, we used the optical flow technique (OFT)³ for movement signal detection and peak detection analysis to calculate CBF, and then compared the accuracy of the two techniques.

MATERIALS AND METHODS

The nasal mucosas were harvested from 50 subjects during surgery. The beating movement of cilia was observed under an inverted microscope at a magnification of ×1000 and recorded in a video file using a commercial high-speed video camera (Moticam 2000, Hong Kong, China). The analysis program was written using C++. As a control, an expert manually determined the CBF by observing the slow-motion videos on a monitor.

The OFT uses pyramidal implementation of the Lucas–Kanade feature tracker between frames to identify the apparent motion of areas of brightness on the image. The areas of image brightness that change over time to provide an image sequence are defined as I(x, y, t). The iterative Lucas–Kanade scheme consists of the following steps:

- At level L, dL, the standard Lucas–Kanade scheme is used for optical flow computation.
- The next pyramid level, L – 1, is estimated.
- Then, gL+1 = 2(gL+dl), dl = d0+g0, V=U+d is calculated.

To compute the CBF, the different signals of the frames were processed using the peak detection method (versus difference image analysis, which subtracts pixels between two continuous frames).

RESULTS

Compared to the control, the accuracies of the OFT and difference image analysis were 90.15% (±8.18 SD) and 84.82% (±11.22 SD), respectively.

CONCLUSION

The OFT with peak detection method was more accurate than difference image analysis in detecting CBF. Measuring the CBF is difficult because it requires sophisticated devices that are technically complex, and complicated software. The software developed for the OFT with peak detection method will be freely available for research purposes.

REFERENCES