E. 結論

3D 内視鏡を使用した腹腔鏡下卵巣嚢腫核出術および子宮筋腫核出術において、手術時間、出血量は従来の 2D 内視鏡と比較し有意差を認めないものの、手術時間の短縮、出血量の減少傾向を認めた。内視鏡画像の 3D 化により、2D 内視鏡では得られなかった、奥行き感の把握、操作性の向上が得られ針の把持や縫合操作など容易となり、スムーズな手術が可能になった。

今回得られた課題を開発サイドにフィードバックし、また超高感度内視鏡カメラの導入などによって、これらの課題がクリアされることで、産婦人科領域の腹腔鏡下手術における手術成績の向上や、手術手技の改善、術者の疲労の軽減に貢献できると考えている。

F. 健康危険情報

統括研究報告書に記載.

G. 研究発表

1.論文発表

該当なし

2.学会発表

該当なし

H. 知的財産権の出願・登録状況（予定も含む）

1. 特許取得

該当なし

2. 実用新案登録

該当なし

3. その他

該当なし

別紙4

研究成果の刊行に関する一覧表レイアウト

書籍

著者氏名	論文タイトル名	書籍全体の編集者名	書　籍　名	出版社名	出版地	出版年	ページ

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Chinzei K., Kobayashi E., Suzuki T., Yamashita J. and Yamauchi Y.	Small Computings for Clinicals and SCC ToolKit, OR friendly Trial Package and Software Development Kit	MIDAS Journal (online)		1-8	2013
柿澤幸成、荻原利浩、本郷一博	2D、3D神経内視鏡併用での経鼻的傍鞍部手術経験	第20回日本神経内視鏡学会抄録集		80	2013
柿澤幸成、荻原利浩、本郷一博	3D神経内視鏡での経鼻的傍鞍部手術の有用性	第24回日本間脳下垂体腫瘍学会抄録集		115	2014
Hisae Aoki, Toshiyuki Mori, Hiromasa Yamashita, Tsuneo Fukuyo, Toshio Chiba	Development of Ultra high sensitivity CMOS HD camera for endoscopic surgery	SAGES2013		http://www.sages.org/meetings/annual-meeting/abstracts-archive/development-of-ultra-high-sensitivity-cmos-hd-camera-for-endoscopic-surgery/	2013
Hiromasa Yamashita, Hisae Aoki, Tsuneo Fukuyo, Toshiyuki Mori, Toshio Chiba	Ultrasensitive Endoscope Using CMOS HD Camera for “Surgery in the Dark”	ACCAS2013 Abstract book		76-77	2013

Small Computings for Clinicals and SCCToolKit, OR friendly Trial Package and Software Development Kit

Release 1.02

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Abstract

This paper is about a design policy for operation-room (OR) friendly research system, software and a software toolkit SCCToolKit for this purpose, and a few examples. Examples are image processor for endoscope, OR event detector, vision based registration of ultrasound and endoscopic images, etc. We name the design policy as Small Computations for Clinicals (SCC). A system is SCC savvy if it is 1) single purpose, 2) turn-key system without need of using mouse and keyboard, 3) small form factor PC based, and 4) cost less than $1,000 USD. SCCToolKit is OpenCV extension that could minimize the number of buffer copies from receiving image frames from operating system to render it to display buffer. It is open source under BSD license. We measured the latency of image capture to display of the endoscope image processor was between 0.1 to 0.2 second for 1920x1080 size display with chroma-key image mixing. Considering of the acceptable latency of 0.2 second, the performance was as good as commercially available, custom hardware processor that could cost over 10,000 USD, while our PC based system cost 773 USD.

Contents

1 Introduction

There have been many research works of computer-integrated surgery (CIS) and computer-assisted interventions (CAI), as well as their clinical applications. Many of these are PC based, software centered systems. Useful software toolkits such as VTK[1], OpenCV[2] are distributed and widely used to build Slicer 3D[3] [1] and other research systems. All these software named here are open source software (OSS). OSS in CIS/CAI research field is more than 'free of charge'; this allowed *quick* delivery of the research achievements from scientists to clinical researchers – 'quick' in comparison to the case the system obtains regulation approval and the researcher obtains purchase approval and document works of the hospital.

We believe that there are yet many unpaved fields where research systems for OR, in particular combination of PC based systems can improve clinical medicine with similar approach Slicer 3D and other OSS projects have been successfully achieved. A requirement is that *OR research systems need to be OR friendly*.

OR Friendliness

We consider the OR friendliness of research systems as the following. Needless to say, the systems should be OR safe. We do not argue safety in this paper.

1) Easy setup and maintenance. OR staff may need to wire, turn on, use, turn off it and do maintenance without developing engineers.
2) Simple user interface (UI). At best, full automatic, no need of manipulating UI or typing keyboard.
3) Simple function. Excessive functions confuse user what they can do.
4) Small size, small footprint. Active OR is often short of space.

These are based on our findings through our observation and experience in OR. Many PC based research systems, mostly we researchers made, were not necessarily OR friendly. They often appeared that

1) We need to install it. OR staffs call us to come and take care of it when they want to change anything.
2) We need to manipulate the program. Sometimes we need to type additional commands or parameters.
3) We need to attend every operation because the system is complicated and delicate.
4) The PC is bulky. Quite often we need to choose such PC to install extension boards for image capture, parallel interface, etc.

However, as technology progressed, PC and peripheral hardware became drastically smaller. We found that we could build OR friendly research systems using these new PC and hardware. This paper first describes *"Small Computings for Clinicals", our design policy to develop OR friendly research systems* and *SCCToolKit, a software development kit.*

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[1] http://www.vtk.org/

[2] http://opencv.willowgarage.com/wiki/

[3] http://www.na-mic.org

2 Small Computings for Clinicals

We defined the following attributes to be OR friendly, hereafter mentioned as 'Small Computings for Clinicals' (SCC) criteria.

1) Small; as small as Apple's Mac Mini[4] or Intel's NUC[5] form factor PCs.
2) Single purpose; preferably a single function per single PC.
3) Turn-key system; program starts by turn on the power switch, preferably UI-less.
4) Low introduction cost; preferably less than 1000 USD.

3 SCCToolKit – OpenCV and Qt extension for image capture and display

SCCToolkit is our extension to OpenCV and Qt widget with following features;

1) Capture classes to replace `cv::VideoCapture` class in OpenCV. It supports USB2.0 cameras and Decklink image capture devices (Blackmagic Design Pty. Ltd.[6]). Example of a Decklink device is in Fig. 1(1). The new classes have the following features.
   - Hot plug/unplug of cameras (OpenCV's `cv::VideoCapture` is not so).
   - Cameras are recognized by hardware unique indices (OpenCV's camera indices are dependent to connection order etc., which are unpredictable and confusing).
   - Sampling timer, either by camera's frame rate or by software timer (OpenCV sample codes often use for-loop).
2) OS X's CoreImage framework (`CIImage` class) support.
3) Extension of Qt widget class that can accept OpenCV's `cv::Mat` and `CIImage` formats.
4) Multi-thread support.

Feature 1) is for better camera support, 1) to 3) are to minimize the number of buffer copies from capture to display[7], and 4) is to use multi-core CPU wisely. `CIImage` and the Qt widget class together work to do image pipeline on the GPU as well as image processing provided by `CIFilter` classes.

Currently, SCCToolKit runs only on OS X 10.7 or later. This is due to the use of CoreImage and libdispatch library and language extension of C/C++. We consider of adding DirectX support and other concurrency programing technique to support Windows. Cmake is used to build SCCToolKit.

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[4] http://www.apple.com/mac-mini/

[5] http://www.intel.com/content/www/us/en/motherboards/desktop-motherboards/nuc.html

[6] http://www.blackmagicdesign.com/

[7] OpenCV's HighGui module is platform independent. OS X version copies 4 times from capture to OpenGL display, and Windows version copies 3 times. SCCToolKit has copies once. HDTV signal is usually in YUV color space, but most of Decklink capture device has hardware YUV to RGB conversion which is significantly faster than software conversion.

Here is a sample code to capture from a Decklink device to a Qt main window. In this sample, sampling rate is defined by the hardware timer of the capture device. When a frame is captured, the callback function `myCaptureCenter::imagesArrived()` is called. It is not called while the device or a camera is disconnected. Similarly, device initialization in `CaptureCenter::addCapture()` silently ignore when the device or camera is not connected.

```
#include <QtGui>
#include "opencv2/imgproc/imgproc.hpp"
#include "CaptureCenter.h"
#include "QCvGLWidget.h"

QCvGLWidget *pwidget;                          // Allocate it in global scope.

class myCaptureCenter : public Cap::CaptureCenter {
    void imagesArrived(Cap::Capture *capture) override;
};

void myCaptureCenter::imagesArrived(Cap::Capture *capture)
{
    Cap::CapturePtrVec::iterator cap = captures.begin();
    if (cap != captures.end()) {
        cv::Mat frame = (*cap)->retrieve(0);
        (*cap)->lock();
        pwidget->updateImage(frame);           // Show image in the widget.
        (*cap)->unlock();
    }
}

int main (int argc, char **argv)
{
    QApplication app(argc,argv);
    QMainWindow window;
    pwidget = new QCvGLWidget;
    window.resize(640, 480);
    window.setCentralWidget(pwidget);
    window.show();
    pwidget.clear();                           // Wipe the window.

    myCaptureCenter capcenter;
    /* Attempt to open a Decklink capture device.
       It is not an error when the device or a camera unconnected. */
    if (capcenter.addCapture(Cap::kCaptureTypeDeckLink) == NULL)
        std::cerr << “Initialization error.” << std::endl;
    capcenter.start();
    app.exec();
    capcenter.stop();
    return 0;
}
```

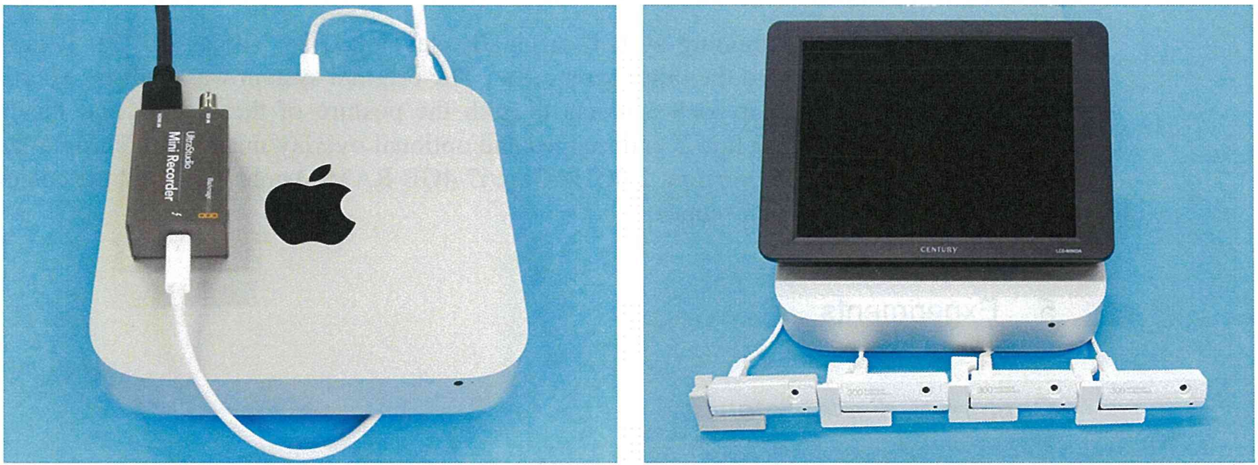
4 Examples of SCC Applications

1) Image processor for stereo endoscope. Its basic role is to convert input image from the endoscope to the output stereoscopic image optimized for display device. The input image is in HDTV format, i.e.,

1920 x 1080 pixel size. The image processor splits a single HDTV image so that left and right channel images fit side by side with the appropriate distance. Optionally it can apply color correction. The commercial products, built with dedicated signal processor, cost around $10,000 USD.

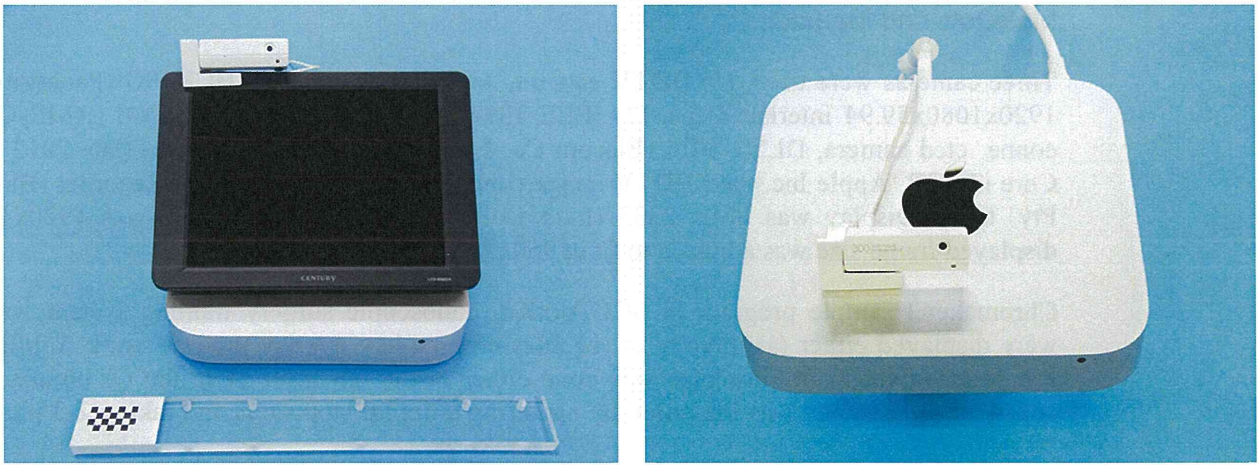
Our SCC version system was developed using SCCToolKit on OS X. The PC was Mac Mini (late 2011 version, 2.5GHz Core i5/4GB RAM, Apple Inc.) and HDTV image capture was UltraStudio Mini Recorder (Blackmagic Design Pty. Ltd.) connected to the PC by a Thunderbolt cable. Video output by an HDMI cable. We discuss its performance later.

2) Four USB-camera event detection and recorder. It was originally developed by Suzuki et. al [2]. The original system could record up to 8 NSTC cameras as well as 8 microphones both installed in an OR. Event was defined as busy-ness of the scene, and detected by observing the compression rate of the video. Two tower size PCs were used to install 2 boards for image capture, 8 sound capture boards.



1) Image processor for stereo endoscope. Small gray box is UltraStudio Mini Recorder.

2) Four USB-camera event detection and recorder



3) Ultrasound – endoscopic image overlay system. A USB camera and a movie file were used instead of endoscope and echo images.

4) VisualLog, device panel logging system.

Figure 1 Four examples of SCC Applications. Currently, only (1) uses SCCToolKit. We are rewriting the rest of examples to use SCCToolKit.

The SCC version system was developed without using SCCToolKit on Windows 7. The PC was Mac Mini (late 2010 version, 2.0GHz Core i7/4GB RAM, Apple Inc.) and the cameras were four USB 2.0 cameras. We limited camera resolution to 640x480. The hard disk was replaced to solid state disk (SSD) for recording performance. We tested it could record at least 12 hours.

3) Pattern tracking based ultrasound – endoscopic image overlay system. Originally developed by Kobayashi et.al., this program was to overlay an ultrasound image in an endoscopic image by tracking a chessboard pattern attached to the ultrasound probe. The hardware was same as the image processor for endoscope, plus another capture device Intensity Shuttle for USB 3.0 (Blackmagic Design Pty. Ltd.) for ultrasound image. The demo system uses a USB camera as alternative to the ultrasound image.

4) VisualLog, device panel logging system. It is to record the log of an OR device by image recognition with a priori information of the device's panel layout.

5) Endoscopic surgery training system originally developed by Yamashita [3]. It has two endoscopic views, one for teacher and the other for student. The original system was built on Mac Pro with 2 NTSC endoscope images plus up to 8 cameras to grab the posture of the teacher and the trainee. The SCC version system simplified it to 2 endoscopes and optional overlay image with chroma-key effect. The PC was Mac Mini (late 2011 version, 2.0GHz Core i7/4GB RAM, Apple Inc.), and the cameras were all USB cameras including the endoscopes.

5 Experiments

Capture to display latency

Endoscopic view should be presented within 0.2 seconds, which is the human perceivable visual vs. motor-sensory latency [4]. We measured the latency from capturing a frame to displaying it.

Materials and Methods

Three cameras were used, (1) HDTV camera, AG-HMR10 and AG-HCK10G (Panasonic Co.), which is 1920x1080x59.94 interlaced fps. (2) IEEE 1394 connected camera, CF-2000 (AME Co.). (3) USB2.0 connected camera, DLY300TA (Elecom Co. Ltd.). The PC was Mac Mini (late 2012 version, 2.6GHz Core i7/8GB, Apple Inc.) and HDTV image capture was UltraStudio Mini Recorder (Blackmagic Design Pty. Ltd.). Display was Foris 2333 (Eizo Co.). The resolution of these was 1920x1080 pixels, and displayed frame size was adjusted to fit in 960x960 pixels.

Chromakey2 sample program in SCCToolKit, endoscopic surgery training system, was used. Frames were displayed either (a) directly or (b) after chroma-key overlay process using Apple's sample code[8]. Image enlargement or shrinkage was done either in the OS layer or in the Qt library, which were not coded by us. Latency was measured by capturing a digital stopwatch and taking 2-3 photos of the watch

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[8] https://developer.apple.com/library/mac/documentation/GraphicsImaging/Conceptual/CoreImaging/ci_filer_recipes/ci_filter_recipes.html

together with the displayed image. We also observed the CPU load using "Activity Monitor.app" supplied with the operating system.

Result

The latencies were between 0.1 and 0.13 seconds for (1) HDTV camera and (2) IEEE 1394 camera, and 0.16-0.2 seconds for (3) USB camera. The difference of image processing (either (a) directly displaying or (b) displaying after the chroma-key process). The CPU load was between 40 – 80%. Note that the CPU has four cores therefore the maximum load can be 400%.

6 Discussion and Conclusion

Performance

The latency of the capture to display was within 0.2 seconds. This latency was satisfactory small comparing to the distinguishable visual to other sensory stimuli timing difference. This result indicated that the current system and software are considered to have substantially equivalent performance compared to commercially used endoscope image processors built with desiccated custom hardware. And the CPU load was up to 80%. We have potential to do more tasks while performing fast capture and display task.

Effect of Simplicity

We are currently planning to apply SCC systems to test in clinical environment; SCC does not have clinical experience yet. We expect that being a turn-key system and eliminating the use of keyboard and mouse will lead to several positive effects; 1) simple wiring and less mistake in wiring, 2) space occupied by these interface devices freed, 3) greater freedom of PC placement, possibly away from PC operator, 4) users cannot error to use the program, 5) user instruction and user support become simple, 6) forcing the program design simpler, forcing programmers to build it so. Saying that, we are also aware of the limitation of doing so; 1) UI-less program has no user control after initial configuration, 2) turn-key system tends to be stand-alone, it is not easy to design to cooperatively work with other computers. We are currently working to add a functionality to remotely configure the program status. The current plan is to use a smart phone as a UI.

Use of small form-factor PCs forces us certain compromise; computations that demand machine power cannot fit. The positive effect is that we can specify the 'suggested' hardware as small PCs widely available in market are limited, and this also helps testing the possible hardware combinations. And another positive effect is that we researchers need to carefully select what is the core function and what is the most important to demo the idea.

Impact of SCC / Disruptive Low Cost

Packaging a system with a small PC brought a significant benefit to reduce the introductory cost. For example, the endoscope image processor example was built of 1) a Mac Mini (599 USD), 2) an HDTV capture device UltraStudio Mini Recorder (145 USD), and 3) a Thunderbolt cable (29 USD): total 773

USD. These items are consumer products and widely available through online shopping. The equivalent commercially used endoscope image processor costs over 10,000 USD.

The other examples, such as the endoscopic surgery training system had the similar tendency. The research systems from research laboratory were expensive, had number of functions that were customizable but required the inventing researcher's attendance to use.

Impact of SCC / Lowering the Barrier to Clinical Persons Try New Technology

We believe that these characteristics of SCC, 1) small, 2) single-purpose, 3) UI-less turn-key system 4) in lower cost will work positively to lower the barrier to try new technology by clinical persons at clinical environment. Because these characteristics will ease certain barriers that often prevent new ideas proceed to clinical research before discussing safety and effectiveness. Trying is crucially important for a new idea to be understood and SCC will contribute to demonstrate the new idea in clinical environment by clinical persons.

Future Extension Plans

We are currently working on the following extensions: 1) remote UI by smartphone or tablet, 2) Windows and Linux support, 3) wiki site for developer and user information and organizing a developer – clinical user community.

Acknowledgement

This work has been partially supported by NEDO P10003 and MHLW H24-Area-Norm-007.

Reference

[1] S. Pieper, M. Halle, R. Kikini. *3D SLICER*. proc. 1st IEEE Intl Symp Biomed Imag: From Nano to Macro 2004; 632-635, 2004.

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[3] J. Yamashita, H. Murata, K. Tomoda, Y. Baba. *An in-situ Tele-mentoring System for Training Endoscopic Surgery in the Operating Room*. Simulation in Healthcare, 7(6):558-9, 2012

[4] W. Fujisaki and S. Nishida. *Audio-tactile superiority over visuo-tactile and audio-visual combination in the temporal resolution of synchrony perception*, Exp Brain Res 198:245-59, 2009.

S2-03

立体神経内視鏡を用いた経鼻手術とその工夫

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【はじめに】現在当院では最近開発された立体神経内視鏡を導入して経鼻手術を中心に手術を行っている。手術中に立体内視鏡を用いた手術操作にはいくつかのピットフォールがあり、今回は当院での立体視に基づく手術環境やその工夫、注意すべき点について報告する。【方法】立体神経内視鏡システムとして、スコープ外径4.7mm、有効長180mmのフルハイビジョン立体内視鏡（町田製作所）を用い、32型３Ｄ LCDモニター（パナソニック製）を頭側に配置する。最適な立体視が可能なように３Ｄモニターは術者の立ち位置から約1-1.5mの距離とする。偏光メガネをかけて立体視による手術操作を行うが、助手以外にも介助ナース、麻酔科医や学生などにも偏光メガネをかけてもらい毎回立体視やその副作用について意見を収集した。これまでに12例（下垂体腺腫９例、頭蓋咽頭腫２例、斜台部腫瘍１例）の経鼻手術を本システムだけを用いて行った。【結果】全例で立体視を行いながらの手術操作が可能であったが、巨大下垂体腺腫、頭蓋咽頭腫、斜台部腫瘍など特に深部操作が必要になる症例で立体視が有効であった。手術時間は平均４時間程度であったが、偏光メガネをかけての立体視操作による副作用は多のスタッフも含めてほとんどなかった。また手術操作中にある程度画面を見る角度や位置を変えても立体視は可能であった。ただし立体内視鏡は先端が２レンズとなっているため一方が汚れると画面は見えていても立体視が出来なくなるので注意が必要である。【結論】現時点での立体神経内視鏡システムの課題は、解像度が２Ｄハイビジョン内視鏡より劣ること、２Ｄ内視鏡より視野角が狭いことである。また立体視についてはその能力や副作用についての個人差が大きいという点を念頭に置く必要がある。しかし立体視での内視鏡操作の有用性は疑いがなく、今後最適な使用法や疾患の選択などについて症例を蓄積する必要がある。

S2-04

２Ｄ、３Ｄ神経内視鏡併用での経鼻的傍鞍部手術経験

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信州大学　医学部　脳神経外科

【目的】２Ｄ神経内視鏡での最大の問題点は奥行きが分かりにくいことである。２Ｄで視認することで、今までの経験を生かし、見え方や内視鏡挿入度合いでその多くは解消しているのは事実ではあるが、実際の奥行きが分かった方が良いのは間違いない。我々は最近立体内視鏡を利用する機会を得たため、倫理委員会での承認の後、傍鞍部腫瘍摘出手術にて使用してみたので、その使用経験を報告する。【対象】2013年3月以降、傍鞍部腫瘍症例15例において立体内視鏡（新興光機製 4.7mm径 0, 30度）を内容説明後、承諾の上使用した。既存の２Ｄ内視鏡システム（Storz製 4mm径 0, 30, 70度）を併用した。【結果】鼻部でのアプローチにおいては細い２Ｄの方が操作性が高く、やや太い３Ｄ内視鏡は血餅の付着にて片目のみとなったり不自由を感じた。蝶形骨洞前壁に至るあたりから蝶形骨洞内操作時には３Ｄ内視鏡の奥行きの観察に有用であり、ドリリングの際の安全性に寄与した。解像度は0.2mmの分解能は２Ｄ、３Ｄともに十分であったが、表示方法のため、縦方向半分となる。色調は２Ｄ、３Ｄで遜色なかった。特に海綿静脈洞内腫瘍浸潤にて正常構造物が壊れている症例において、腫瘍摘出時の２Ｄ観察下では分かり得なかった奥行きを３Ｄ利用で把握され、安全性向上に寄与した。発熱は、手で感知できないほどであった。偏光眼鏡を装着するため、特有の薄暗さを感じたが、見えるべき組織が見えないということはなく、眼精疲労は感じなかった。３Ｄ内視鏡使用による合併症はなかった。【結語】従来顕微鏡下経鼻的手術において術者以外には分かり得ない部分が多々あったが、このシステムを利用することで、手術場にいる全員が経験を共有できるため、教育面で有利である。現時点においては３Ｄ内視鏡のみでの手術は解像度の点で問題が生じ、２Ｄ内視鏡との併用が望ましいと言えるが、更なる機器の発展により３Ｄ内視鏡の活躍する機会が増えると思われる。

O9-1

内視鏡下経鼻下垂体腫瘍摘出術でのヘッドマウントディスプレイの使用経験

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【はじめに】下垂体部病変への手術は周辺器具の進歩に伴い、顕微鏡手術から内視鏡手術へ、さらに内視鏡はハイビジョン化、そして今後は3D内視鏡の導入が見込まれる。そんな中、医療用として、新たな内視鏡モニターとして発売されたヘッドマウントモニター（Sony製、HMS-3000MT）を当院下垂体手術で使用する機会を得たので、その使用経験を報告する。【機器】ヘッドマウントモニター（HMM-3000MT）・ヘッドマウントイメージプロセッサユニット（HMI-3000MT）、内視鏡システム（STORZ IMAGE1 HUB HD、4mm硬性鏡）、ナビゲーション（StealthStation）。【方法】非機能性下垂体腺腫に対する、耳鼻科・脳神経外科共同での内視鏡下経鼻腫瘍摘出術。術者・助手はそれぞれにヘッドマウントモニターを装着し、看護師などそれ以外のスタッフは通常通りのモニターで観察。【結果】モニターの重さは今回の操作時間（3時間弱）ではそれほど気になることはなかった。また顔の位置を自由に保つことができる為、特に助手では楽であった。モニター装着中も目線を下に向けることで直視下の操作が概ね可能であった。ナビゲーション画像は切り替えでフル画面表示やPinP表示することも可能であった。見え方は、両眼前に画像が占められることで臨場感と立体感が得られる印象であった。ただ設定（レンズの幅、固定バンドの位置・強さ、など）がずれた時にはピントがずれたり画質が低下する為、使用者が不潔になるか介助者の助けを要した。【結語】装着後の微調整時などが必要な際などの不自由はあるものの、通常モニターでは感じにくい臨場感や立体感が感じられた。今回は機会がなかったが、3D内視鏡ではよりその恩恵が得られることが期待される。

O9-2

3D 神経内視鏡での経鼻的傍鞍部手術の有用性

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【目的】2D神経内視鏡での最大の問題点は奥行きが分かりにくいことである。2Dで視認することで、今までの経験を生かし、見え方や内視鏡挿入度合いでその多くは解消しているのは事実ではあるが、実際の奥行きが分かった方が良いのは間違いない。我々は最近立体内視鏡を利用する機会を得たため、倫理委員会での承認の後、傍鞍部腫瘍摘出手術にて使用したので、その使用経験を報告する。【対象】2013年3月以降、傍鞍部腫瘍症例23例において立体内視鏡（新興光機製 4.7mm径 0, 30度）を内容説明後、承諾の上使用した。既存の2D内視鏡システム（Storz製 4mm径 0, 30, 70度）を併用した。【結果】鼻内では若干3D内視鏡の太さにおいてわずかに不利ではあるが、鼻内構造物の把握において良好な視野が得られた。蝶形骨洞前壁に至るあたりから操作感の不自由さは減り、腫瘍摘出に際しても奥行きが分かることで摘出時の無駄な操作は減った。解像度は理論的に3Dでは半分とされるが、特に問題とならなかった。色調は2D、3Dで遜色なかった。特に頭蓋底腫瘍の浸潤にて正常構造物が壊れている症例において安全性向上に寄与した。発熱は、手で感知できないほどであった。縫合針の把握が容易であった。偏光眼鏡を装着での薄暗さを感じたが、眼精疲労は感じなかった。レンズを回旋した場合、天地がずれるため手元操作の不具合の可能性はあった。3D内視鏡使用による合併症はなかった。【結語】3D内視鏡を利用することで、手術場にいる全員が経験を共有できるため、教育面で有利である。顕微鏡術者から内視鏡への移行へのハードルは下がるであろう。現状において3D内視鏡に弱点はあるが、今後さらに開発が進めば、より重視されるツールとなると実感した。

O9-3

経鼻下垂体手術における術中モニタリングの適応と限界

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【はじめに】経鼻内視鏡手術は拡大術が施行されるに伴い、術後に視機能障害など神経症状が悪化する危険性がある。我々が経鼻下垂体手術に用いている術中モニタリングの適応と限界について検討した。

【対象・方法】対象は2009年以降に当科で経鼻内視鏡手術を施行した症例のうち、術中に視機能に影響がおよぶと考えられ、術中VEPおよび眼球運動のモニタリングを行った下垂体腺腫の23例である。

【結果】VEPは20例に行ったが、すでに眼球が摘出されていた1例1眼と高度に視力が低下していた1例1眼に対してはVEPを施行しなかった。VEPの振幅が不変であったものは25眼でそのうち術前に完全な両耳側半盲を来していた症例の1眼で術後に視機能が悪化した。13眼にVEPの振幅の変動を認めたが、手術終了時にはVEPは回復傾向にあり術後に視機能が悪化した症例はなかった。眼球運動のモニタリングは海綿静脈洞内の動眼神経や外転神経の同定に有用であったが、モニタリングを行ったとしても海綿静脈洞内の腫瘍摘出には限界があった。

【結論】術中モニタリングにより手術操作を中断したり剥離操作を変更することにより症状の悪化を防ぐことが可能であった。VEPは術前の視機能障害が高度である場合には視機能の悪化を捉えることが困難な症例があるため、注意が必要である。また、眼球運動のモニタリングを用いることで海綿静脈洞内の病変に対してより安全にアプローチが可能となるものの、モニタリングにより海綿静脈洞内の腫瘍の摘出を向上するか否かについては今後症例を積み重ね、検討する必要がある。

Development of Ultra high sensitivity CMOS HD camera for endoscopic surgery

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Objective of the device

Laparoscopic surgery has been spread rapidly with development of equipment. Laparoscopic surgery is performed while watching the image that is projected on the monitor out, and that is required high quality image. So in the field of the camera, development has been progressed remarkable such as high-definition camera and 3D camera. In a high-quality surgical endoscope system is now obtained by the 3CCD system. However it is difficult to watch operating area under low-light. The endoscope light source currently being commonly used 6 lux. In the scope of the small diameter, the amount of light (6 Lux) will not be enough light to see. Also there is another problem. It's possible to happen complications such as burn caused the light source. We developed new camera that use CMOS image sensor and could be made more sensitivity. Using those camera can be made comfortable to watch and operate and doesn't need powerful light source.

Description

As a feature, it is an ultra-sensitive and high-definition. It has a wide range of spectral sensitivity characteristics. Unlike the CCD, this camera is not required the cooling system. Miniaturization is possible. And less power consumption could be possible. It's used a 2/3 inches format color CMOS image sensor as the imaging device. The number of output pixels 1.47 million pixels. Minimum illumination is 0.01LUX. The camera head is 50mm (W) × 50mm (H) × 50mm (D). Head weight is 170g. It can be connected to all the rigid endoscope.

Preliminary results

Using ultra high sensitivity CMOS HD camera, images were taken dark field to the bright field. In general illuminance of the meeting room is 300-800 lux and under the street light is 1-5 lux. The illuminance under moonlight is 0.01- 0.1lux. The quality of images taken with a 300 lux and images taken with 1 lux illumination was comparable.

Conclusions/Future directions

Ultra high sensitivity CMOS HD camera could be advanced development in laparoscopic surgical field. It can be expected to spread in the field of laparoscopic surgery as well as for fetal surgery area, the field of ophthalmology. Moreover, further miniaturization is possible in the near future and it would be cost savings. We have now developed a greatly improved version with CMOS image sensor. This camera is a powerful tool for watching surgical area at low-light conditions. In future we will need to experiment for practical use.

Session: Poster Presentation

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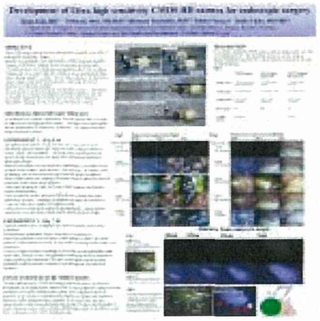

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Ultrasensitive Endoscope using CMOS HD Camera for "Surgery in the Dark"

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Abstract: Recently needs of more sensitive imaging device becomes higher in laparoscopic surgery. In this paper we propose a new endoscope using CMOS HD camera for ultrasensitive color imaging. For feasibility study, at first we compared visible imaging with our camera using a single LED light and a conventional 3CCD camera using 300W xenon light source. Next we compared fluorescence imaging of indocyanine green with our camera and previously developed EM-CCD camera. Our camera can detect color image of target object under only 1/100 illumination intensity condition using a single LED light. About fluorescence imaging, our camera can display brighter ICG light than EM-CCD camera. In conclusion, our new ultrasensitive endoscope using CMOS HD camera performed clear visible imaging under weak light using only a single LED light, and bright fluorescence imaging of ICG. For future works, we will evaluate the camera *in vivo* experiments.

1. Introduction

In laparoscopic surgery conventional endoscopes require strong light source of a few dozen to hundred watt with strong light and heat, which involves occasional intraoperative thermal burn. And smaller endoscopes for minimal invasive surgery require stronger light source because of a small number of light fibers for illumination. On the other hand for endoscopic imaging of involvement of lymph nodes, some devices to detect faint fluorescence are necessity. For these issues, needs of more sensitive imaging device becomes higher.

We have already developed high sensitive endoscopic camera using a high-gain avalanche rushing amorphous photoconductor (HARP) [1] and fluorescence endoscope with high sensitive CCD camera [2, 3]. In this paper we propose a new endoscope using CMOS HD camera for ultrasensitive color imaging.

2. Method

Our new CMOS HD camera with 10mm endoscope is shown in Fig. 1, and its specifications are in Table 1. The camera head is connectable to current standard rigid endoscope. The CMOS image pickup device performs more sensitive imaging than conventional endoscopic camera by specific integral elongation treatment of maximum 64 times. In addition the camera has broad spectral sensitivity characteristic to detect near-infrared light.

For feasibility study, at first we compared visible imaging with the new CMOS HD camera using a single LED light driven by 4.5 volt button battery and a conventional 3CCD camera (specifications are in Table 2) using 300W xenon light source. Next, we compared fluorescence imaging of indocyanine green (ICG) with the new CMOS HD camera and previously developed EM-CCD camera (specifications are in Table 3). We used 300W xenon light source to excite ICG, which is excited by around 800 nm light and emits 845 nm near-infrared light. In these comparisons, we used a 10-mm endoscope (SK-2D10SK, Shinko Optical Co. Ltd).

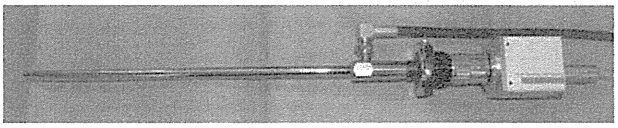

Fig. 1. New CMOS HD camera with 10mm endoscope.

Table 1 Specifications of the new CMOS HD camera.

Image sensor	2/3 inches CMOS
Output pixel	1.47 million
Camera head dimensions	45(W) x 45(H) x 50(D) mm
Weight of camera	170 g
Cooling system	Unnecessary

Table 2 Specifications of the conventional 3CCD endoscopic camera.

Image sensor	1/3 inches CCD
Output pixel	0.33 million
Camera head dimensions	38(W) x 48(H) x 55(D) mm
Weight of camera	100 g
Cooling system	Unnecessary

Table 3 Specifications of the previously developed EM-CCD fluorescence endoscopic camera.

Image sensor	2/3 inches EMCCD
Output pixel	0.33 million
Camera head dimensions	65(W) x 65(H) x 65(D) mm
Weight of camera	218 g
Cooling system	Necessary

3. Result

3.1 Visible imaging comparison

Results of comparison are shown in Fig. 2. To measure illumination intensity of endoscope, we used a light meter (DT-1308, CEM). Illumination intensity conditions in the comparison are shown in Table 4.

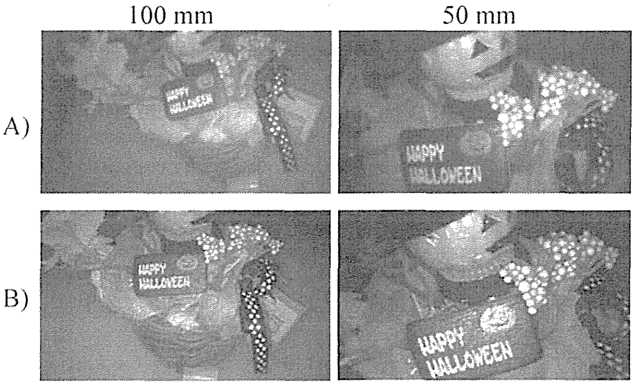

Fig. 2 Visible imaging with the new CMOS HD camera using a single LED light (A) and a conventional 3CCD camera using 300W xenon light source (B). Distances from an object to distal end of the endoscope are 100 mm and 50 mm,

Table 4 Illumination intensity conditions in the comparison of visible imaging.

Distance from target	100 mm	50 mm
Single LED light	100 lx	200 lx
Xenon light source	10,000 lx	20,000 lx

3.2 Fluorescence imaging comparison

Results of comparison are shown in Fig. 3. We used xenon light source with fluorescence filter, of which illumination intensity conditions were same as 3.1. Target object was ICG solution (2.5 x 10^{-2} mg of ICG + 5% albumin) in a microtube. Distances from an object to distal end of the endoscope are 100 mm and 50 mm,

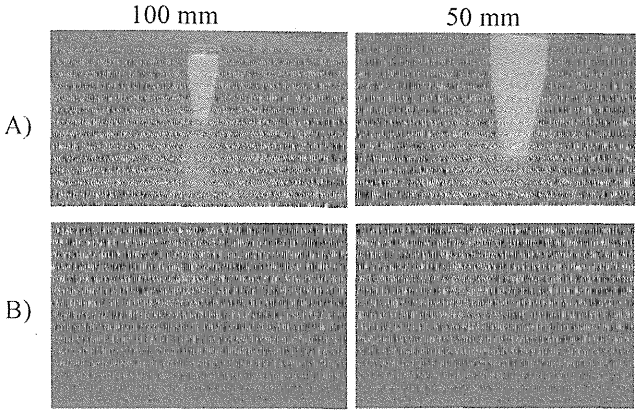

Fig. 3 Fluorescence imaging of indocyanine green (ICG) using 300W xenon light source with the new CMOS HD camera (A) and a EM-CCD camera (B).

4. Discussion

We developed ultrasensitive endoscopic camera using CMOS HD imaging pickup device. Our camera can detect color image of target object under only 1/100 illumination intensity condition using a single LED light, contributing to electric power saving "Surgery in the Dark". Furthermore our camera can give bright 3D endoscopic view through a couple of extremely small lenses in small 3D endoscope (e.g. HD-5.4S, Shinko Optical Co. Ltd).

About fluorescence imaging, our camera can display brighter ICG light with hboring region than EM-CCD camera because of its broad spectral sensitivity characteristic. For next step, we will examine imaging of ICG in blood vessels of animals.

5. Conclusion

Our new ultrasensitive endoscope using CMOS HD camera performed clear visible imaging under weak light using only a single LED light, and bright fluorescence imaging of ICG. For future works, we will evaluate the camera *in vivo* experiments.

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