Research Paper

A New Modified Video Solution System for Neuroendoscopic Procedures

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Citation Seddighi AS, Nikouei A, Seddighi A, Hosseini M, Hosseini M, Zali AR, et al. A New Modified Video Solution System for Neuroendoscopic Procedures Iran J Neurosurg. 2022; 8:E2. http://dx.doi.org/10.32598/irjns.8.2

doi http://dx.doi.org/10.32598/irjns.8.2

Article info:
Received: 10 Jan 2022
Accepted: 25 Mar 2022
Available Online: 07 May 2022

Keywords:
Neuroendoscopy, Neurosurgery, Video recording

ABSTRACT

Background and Aim: Today, neuroendoscopic surgery is gaining popularity because of its minimal damage to normal structures, fewer complications, and excellent clinical results. Using an endoscope and related instruments, surgeons can perform complex surgeries through small incisions, especially for minimally invasive spinal and brain surgeries. Neuroendoscopic systems are currently costly and not portable. Our new video solution is portable at a lower cost and can display and record images in 4K resolution.

Methods and Materials/Patients: We modified the GoPro Hero 6 camera to serve our purpose. By detaching the original camera lens and its front part and replacing the removed parts with a new design, we made a C-mount camera that can connect to a standard C-mount coupler and various common scopes. For color correction, we used an IR-cut filter in front of the camera sensor.

Results: By changing some parts of the camera and connecting it to a C-mount coupler and a scope lens, we made a small, portable neuroendoscope that displays and records images in clear, sharp, high resolution, with a high frame rate.

Conclusion: The modified GoPro camera can be used as an alternative and unexpansive neuroendoscope system for education or treatment in medical centers in developing countries.

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Highlights

- We modified the GoPro Hero 6 camera.

- In our model, the cost of the camera and the endovision system is so much reduced compared with available HD systems.

- Our model provides 4K colored high resolution operative images which are easily recordable.

Plain Language Summary

Neuroendoscopic surgeries are now considered as essential methods for sophisticated brain surgeries, however HD endovision systems are expensive and not accessible. The presented new video solution is portable at a lower cost and can display and record images in 4K resolution and displays and records images in a clear, sharp, high-resolution fashion, and applicable in developing countries.

1. Introduction

For the first time in 1910, L'Espinasse performed endoscopic neurosurgery to accomplish fulguration of the choroid plexus in two infants with hydrocephalus. One of the infants was successfully treated using a cystoscope [1-3]. In 1922, a failed endoscopic choroid plexectomy was performed by Walter Dandy [4]. In 1923, Mixer performed the first successful endoscopic third ventriculostomy (ETV) in a 9-month-old girl with obstructive hydrocephalus using a urethroscope [5]. In 1935, Scarff recorded an initial report on using a new endoscope equipped with a cauterizing electrode, an irrigation system to prevent ventricular collapse, and a rotating head at the endoscope tip to perforate the floor of the third ventricle [1, 3]. The field of neuroendoscopy remained unchanged until 1970, but interest in ETV for the treatment of obstructive hydrocephalus increased again with the improvement of endoscopic imaging. ETV is currently the first choice to treat obstructive hydrocephalus following benign occlusion of the aqua duct or mass lesions around the aqua duct [1, 2].

Currently, neuroendoscopy has gone beyond ventricular-related operations. It is used to treat various treatable diseases, such as intracranial cysts, intraventricular tumors, hypothalamic hamartomas, skull base tumors, craniosynostosis, and spine degenerative diseases. Improving the vision system and illumination of endoscopes allows having neuroendoscopic surgery on the brain parenchyma. The concept of a craniotomy from a keyhole coupled with a selected trajectory makes it possible to use an endoscopic approach to intra-parenchymal lesions using the navigation system. After this advancement, endoscopic resection is possible with the help of various instruments such as a suction tube, tumor forceps, micro-scissors, and monopolar or bipolar techniques through a sheath. Complete or partial resection of the lesion depends on the nature of the tumor. The selection of these patients for endoscopic procedures is still limited and includes cases such as cavernous angiomas, intra-parenchymal hematomas, cerebellar infarctions, and brain abscesses [2]. Recently, many neurosurgeons have used the neuroendoscope as an adjunct to microsurgery of the skull base. The endoscope is often used to look at the corners of the dura or bone areas and neurovascular structures to avoid excessive retraction and drilling at the skull base. Endoscope-assisted microsurgery has been approved as a useful method for the surgery of skull base brain tumors such as pituitary tumors, craniopharyngiomas, acoustic neuromas, epidermoids, and aneurysm clips trigeminal microvascular decompression [2]. Therefore, improving the neuroendoscope vision system and its portability can significantly increase its efficiency in neuroendoscopic procedures.

2. Materials and Methods

We used the GoPro Hero 6 camera to modify it to build a portable neuroendoscope. No specific changes were made to the camera's internal components, such as the sensor and other hardware components. Major changes were made to the front of the camera, which included a lens mount connection. After removing the main lens located on the front of the camera, a metal plate with the dimensions of the front surface of GoPro was first designed and replaced with the detached part. In front of the sensor opening, which is located behind the camera lens, a CS-mount connection was designed to fit the dimensions of the camera and attached to the metal plate that was already put there. The thickness of this connection creates a distance of 12.5 mm between the front surface of the sensor and the lens. According to the couplers of different brands used for neuroendoscopy, which is placed between the camera and the scopes of the neuroendoscope, a C-mount connection with a diameter of 5 mm was designed and attached to the initial CS-mount unit (Figure 1). The distance between the sensor surface and the coupler lens surface with the C-mount connection will be 17.5 mm. This C-mount connector comes standard with a 1-inch thread diameter and 32 threads per inch (TPI). Depending on the type of surgery performed by the neuroendoscope, the presence of blood, and the color spectrum, which is mostly red, an IR-Cut filter was fixed in front of the camera sensor with the help of a thin rubber ring. The thickness of this filter is 1 mm, and its diameter is 19 mm. This filter blocks wavelengths above 650 nm, including infrared waves, and prevents these wavelengths from reaching the camera sensor. So the images will be more accurate and clear. Eventually, by connecting a coupler to the C-mount connection, which is used to connect neuroendoscopic lenses, we will have a portable neuroendoscope that can link to various common lenses with clear and accurate images (Figure 2). The coupler used in this study is a zoom lens type, and its focal length varies from 18 to 35 mm.

3. Results

By detaching the front part of the GoPro Hero 6 camera, replacing it with C- and CS-mount connection, and placing a filter in front of the camera sensor, we built a portable camera for neuroendoscopy that can attach to C-mount couplers and scopes (Figure 2).

4. Discussion

The cost of 4K neuroendoscopic systems is more than $45000 in flagship brands such as Stryker and Ikegami. In this regard, having a portable neuroendoscopy small system with a maximum resolution of 4K and lower cost is required for centers with lower budgets in developing countries. High-resolution images and accurate colors are very effective in the surgeon's performance and the result of surgeries such as neuroendoscopy, which are directly related to the operation's images and surgeon's decisions in real-time. The current system, a modified GoPro camera, is a new solution for performing neuroendoscopic surgeries with a neuroendoscope that costs less than a thousand dollars. Our new device can connect to standard C-mount couplers based on its C-mount interface. Attaching the coupler to the camera allows us to use standard scopes, including STORZ scopes, which are the most commonly used lenses, to the camera. The coupler that we used has a focus ring to adjust for clear and sharp images and a ring to change the focal length from 18 to 35 mm. This camera has a sensor with a size of 1/2.3 inch (6.17x4.63 mm) and a complementary metal-oxide-semiconductor type. The scanning system in this camera is progressive and not interlaced so that the image will be clear, and we can see the entire video frame on the screen simultaneously without any noise and horizontal lines. This modified camera can record video simultaneously in a micro internal memory card with maximum resolutions of 3880x2880, 3840x2160, 2704x1520, and 1920x1080, an aspect ratio of 16:9, and a maximum of 30, 60, 120, and 240 frames per second (fps), respectively. The high frame rate of the modified camera allows the surgeons to synchronize their hand movements with images in real-time. By adjusting the camera's color temperature to about 5000°K and with the help of the IR-cut filter that we put in front of the camera sensor, we will have clear images with a natural color spectrum. The camera's video output is in micro-HDMI, and the output format is H.264 MP4. This generation of video compression standard allows capturing larger video content, such as 4K @ 60fps and 1080p @ 240fps, roughly half the file size with equivalent image quality.

The ability to connect the camera via a Wi-Fi network to a mobile phone or laptop allows having surgical video on both phone and laptop in real-time, which can be helpful and educational for neurosurgery residents. With the GP1 chip, we fully stabilize all three axes, including in 4K @ 30fps and 1080p @ 120fps modes. The dimensions and weight of this modified camera are approximately the same as the original product, with the specification of 6.5x4.5x3.5 cm (W×H×D) and 116 g weight. So, because of its size and dimensions, it fits easily in hand. In many medical centers in developed countries, neurosurgeons can perform microsurgery techniques, endoscopic trans-sphenoid approach, ventricular manipulations, extra-axial, intra-axial lesion surgery, and computer-assisted neuro-navigation using neuroendoscopy [6]. To be more specific, the authors report successful neuroendoscopic techniques for the following disorders: colloid cyst, fibrous pituitary adenoma, prolactinoma, craniopharyngioma, pineoblastoma, tuberculum sellae meningioma, loculated hydrocephalus by cyst fenestration [7]. Developing flexible and rigid endoscopes by Hopkins, mounting optical equipment such as fiber optics, glass-rod scopes, viewing lenses to

Iranian Journal of NEUROSURGERY

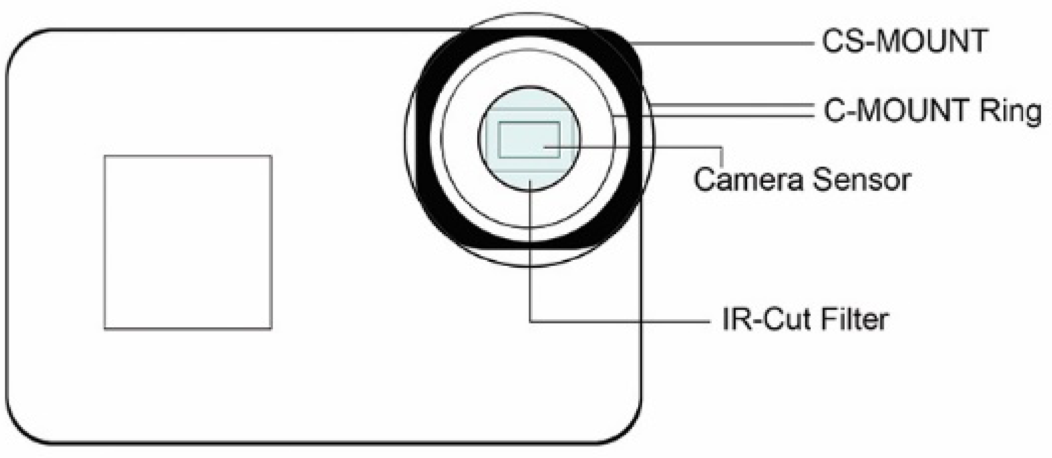

Figure 1. Schematic presentation of modified GoPro camera

enable wide visual angles for the surgeon, and recording and non-recording cameras with various types of lenses have led to the improvement of the quality of neuroendoscopic techniques [8].

Neuroendoscopic advancements experienced a remarkable improvement in 1990 by developing a flexible fiber-optic device with a 75-degree field of view, depth field of 3 to 50 mm, and 30 cm length for ventriculoscopy [9]. Seven years later, Inui et al. assembled a monopolar coagulator for the later ventriculoscope and successfully decreased its diameter from the previous 2.2 mm value [10]. Following the introduction of the thecaloscope in 2001, Warnke et al. expanded previous boundaries of neuroendoscopic procedures, which were limited to cranial disorders, to achieve an endoscopic surgical view for thecal sac lesions and other spinal disorders [11]. In 1998, Perneczky and Fries succeeded in integrating a rigid endoscope with a viewing angle of 0 to 110 degrees and a diameter of 2 to 5 mm with the microsurgery setting [12]. This innovation extended the visual perception of minimally invasive surgery (MIS) techniques until, three years later, Tamaki et al. proposed a solution for so-called “dark areas” to microscope’s view by a combination of an angled rigid endoscope with a viewing angle of 75 degrees, the diameter of 2.7 mm, and depth of focus of 2 to 50 mm to create a picture in picture feature, with simultaneous display of endoscopic and microscopic images [13]. Due to limited capacity to maneuver, adjacent vital neuro-

Figure 2. Demonstration of Modified GoPro Camera With a Coupler, Scope, and Light Attachment

vasculature, and unique anatomy of cerebral ventricles, concerns have been rising for a safe and effective MIS approach to the ventricular system using neuroendoscopy. However, Nishiyama et al. applied a light-emitting diode (LED) processor to the endoscope's display, which resulted in higher contrast pictures [14]. Our priority to apply the camera to the neuroendoscope was to maintain the surgeon's maneuver during the operation, similar to commercially available neuroendoscopes with optical technologies. Thus, the camera's low weight, high definition video recording, significant cost savings compared to similar technologies, and a system processor with great performance are advantages of our new modified video solution on neuroendoscopes. We consider the mentioned features of our new design as a significant advantage in developing countries for the utilization and efficiency of neuroendoscopes in various neurosurgical procedures, which require expensive commercially available neuroendoscopic utilities.

5. Conclusion

The cost of 4K quality neuroendoscope systems is very high. So, the need to use high-resolution imaging systems in this surgical procedure justifies using cameras the same size as GoPro in developing countries with lower budgets in medical centers. It can also help train animal models and simulators.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Conception and design: Amir Saied Seddighi, Afsoun Seddighi, and Morteza Hosseini; Data collection: Amir Nikouei and Yasaman Arjmand; Data analysis and interpretation: Alireza Zali and Mostafa Hosseini; Drafting the article: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, Amir Nikouei, and Yasaman Arjmand; Critically revising the article: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, Alireza Zali, and Mostafa Hosseini; Reviewing the submitted version of manuscript: Amir Saied Seddighi, Afsoun Seddighi, and Morteza Hosseini; Approving the final version of the manuscript: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, Alireza Zali; Drafting the article: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, Amir Nikouei, and Yasaman Arjmand; Critically revising the article: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, Alireza Zali, and Mostafa Hosseini; Reviewing submitted version of manuscript: Amir Saied Seddighi, Afsoun Seddighi, and Morteza Hosseini; Approving the final version of the manuscript: Amir Saied Seddighi, Afsoun Seddighi, Morteza Hosseini, and Alireza Zali.

Conflict of interest

The authors declared no conflict of interest.

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