Integrated image monitoring system using head-mounted display for gasless single-port clampless partial nephrectomy

Kazunori Kihara[1], Kazutaka Saito[1], Yoshinobu Komai[2], Yasuhisa Fujii[1]

[1]Department of Urology, Tokyo Medical and Dental University Graduate School, Tokyo, Japan
[2]Department of Urology, National Cancer Center Hospital East, Chiba, Japan

Videosurgery Miniinv 2014; 9 (4): 634–637
DOI: 10.5114/wiitm.2014.44155

Abstract

A novel head-mounted display (HMD) offers a higher quality of endoscopic imagery in front of the eyes regardless of head position. We present an application of the HMD system as a personal integrated multi-image monitoring system in gasless single-port clampless partial nephrectomy (PN). Our HMD system displayed multiple forms of information as integrated, sharp, high-contrast images both seamlessly and synchronously using a four-split screen. The surgeon wearing an HMD display could continuously and simultaneously monitor the endoscopic, three-dimensional (3D) video and intraoperative ultrasound images. In addition, the operator can rotate the 3D video image using fingertip movements on the finger tracking system. All two clampless partial nephrectomies were safely completed within the operative time, blood loss was within usual limits and there were no complications. The integrated image HMD system might facilitate maneuverability and safety in minimally invasive clampless PN.

Key words: *clampless, partial nephrectomy, three-dimensional image.*

Introduction

Partial nephrectomy (PN) for renal cell carcinoma remains the standard of care for most small tumors because of its oncological equivalence and functional superiority to radical nephrectomy [1]. Clampless PN has emerged as a procedure that avoids renal ischemia and reperfusion injury, and maximally preserves renal function compared with conventional partial nephrectomy with renal hilar vascular clamping [2].

To precisely resect the tumor with adequate management of bleeding and without vascular clamping, it is necessary to accurately locate tumor and intrarenal vasculature. We have applied computer-generated three-dimensional (3D) computed tomography (CT) image segments to visualize the intrarenal relationship between the tumor and the vasculature for clampless PN [3].

A novel head-mounted display (HMD) system offers simultaneous, high quality magnified 3D imagery in front of the eyes [4]. This affordable display system also provides various images, in addition to those from the endoscope, such as the ultrasound probe. The application of the 3D-HMD system to gasless single-port clampless PN has been reported elsewhere [5, 6].

We applied a new personal HMD system, which integrates multiple forms of information in front of the eyes, including a 3D image rotated by the motion of the surgeon's finger. We present here an introduction of the integrated image HMD system for gasless single-port clampless PN.

Case report

The novel integrated image HMD system was applied to gasless single-port clampless PN in two

Address for correspondence
Kazunori Kihara MD, PhD, Department of Urology, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-Ku, Tokyo 113–8519, Japan, phone: +81 3 5803 5295, fax: +81 3 5803 5295, e-mail: k-kihara.uro@tmd.ac.jp

renal tumor patients. Both patients were female and their ages were 61 and 56 years. Clinical stages of the renal tumors were both T1a. Informed consent for gasless single-port clampless PN using the HMD system was obtained.

The principal technique of gasless single-port clampless PN has been described elsewhere [7]. Briefly, after making a single port of around 4 cm, the kidney was mobilized to allow PN just beneath the single port. The tumor was excised using a three-step procedure. First, the resection margin of the renal parenchyma was coagulated and a groove around the tumor was created using ultrasonic coagulating devices. Second, the bottom of the groove was taped to create a "mushroom stalk" shape at the tumor base. Finally, the mushroom stalk where the tumor vessels are often located was transected. All procedures were performed without vascular clamping, and we refer to the technique as the mushroom technique. The parenchyma was not sutured unless vessels in the renal hilum were clamped on demand.

The 3D image of the kidney that underwent this procedure was constructed from CT segmental images using a workstation running Synapse Vincent (Fuji Medical Systems, Inc., Tokyo, Japan), as previously reported [3]. The 3D video image was then created and downloaded to external media in QuickTime format. Some modifications, such as semi-transparent mode, can be added to the obtained 3D image. The targeted region involving the tumor can be removed from the reconstructed 3D image, which can be rotated in any direction.

The gasless single-port clampless PN was performed using a 3D flexible endoscope (Olympus, Japan) (Photo 1). The endoscopic image, 3D image, 3D video image and intraoperative ultrasound image were sent to a high-definition HMD (HMM-3000MT; Sony, Tokyo, Japan) through a multiplexer (VPM-H1,

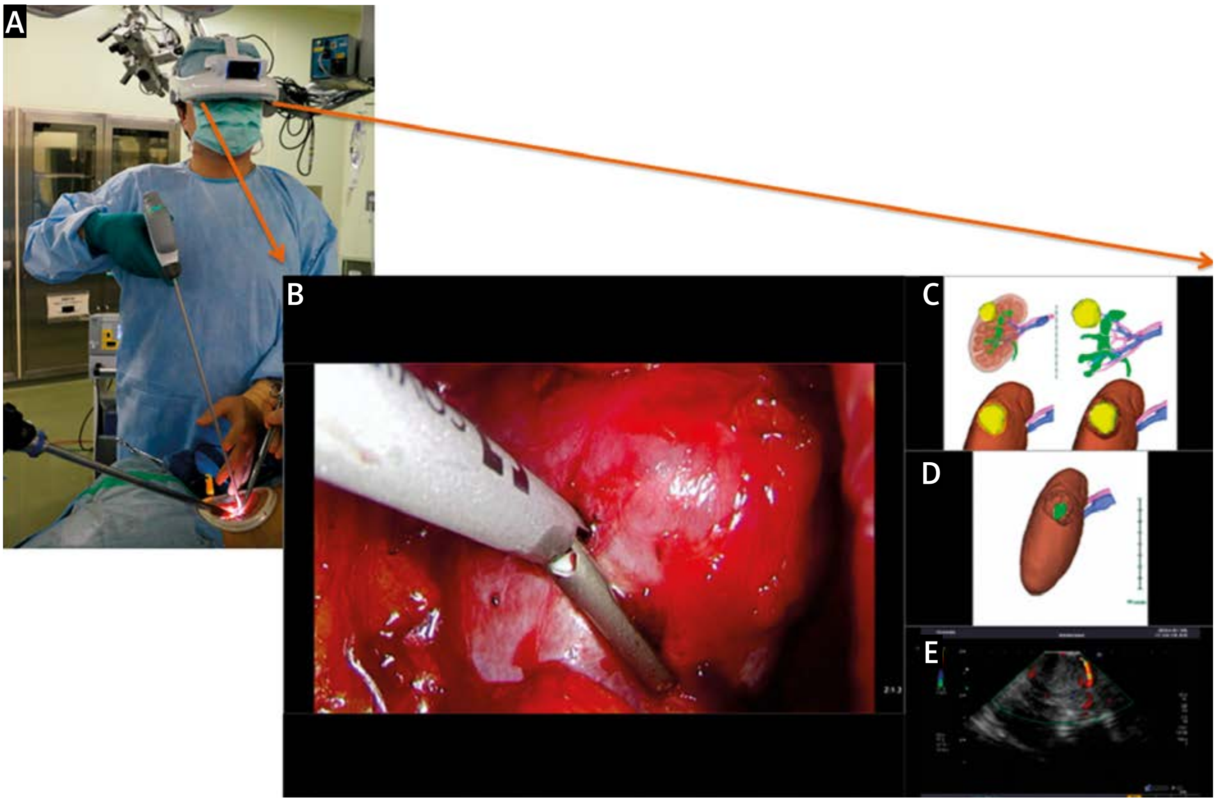

Photo 1. A scene of gasless single-port clampless partial nephrectomy performed using the head-mounted display system (HMD). **A** – The operator resects the kidney parenchyma using an ultrasonic coagulating device while looking at the integrated multiple image in the HMD. The HMD provides the endoscopic image (**B**), 3D image (**C**), 3D video image (**D**) and ultrasound image (**E**) simultaneously as integrated image information in front of the eyes in the HMD monitor. The 3D video image is rotated to adjust the direction to the endoscopic view to confirm the location of the tumor (arrow head) and related structures

MEDIA Corporation, Hyogo, Japan). These images were integrated in the HMD display on a four-split screen, as reported previously [8, 9] (Photo 1). By wearing an HMD system, all the participants could simultaneously and continuously monitor the endoscopic view and 3D images in an ergonomically natural position during the operation and use direct vision by glancing downward. During the operation, the operator can rotate the 3D video image in QuickTime format with their fingertip using the finger tracking system as reported elsewhere [10] (Photo 2). The fingertip movement is tracked through a video camera mounted on the HMD. The software converts an HMD-mounted image into a binary image based on the color green to detect and track the green surgical globe in real time. The direction of the 3D video image was adjusted to the endoscopic view to confirm the location of the tumor and related structures at the site (Photo 2).

Both clampless PNs were safely completed within a normal operative time, blood loss was within the usual limits, and there were no complications. The tumor was excised based on 3D images and ultrasound findings. All participants confirmed that the intrarenal structure around the tumor was consistent with the 3D image. No participants experienced any HMD-wear related adverse effects.

Discussion

In the current study, we demonstrated the application of a novel integrated image HMD system to the gasless single-port clampless PN. During this procedure, all participants wearing the HMD continuously and simultaneously assessed multiple-image information displayed in the HMD.

The integration of radiologic information for PN is required for precise tumor excision that results in acceptable cancer control and maximal preservation of renal function. Accurate localization of intrarenal vasculature leads to appropriate management of intraoperative bleeding in clampless PN. This novel HMD system allows integration of preoperative radiological findings with real-time endoscopic image

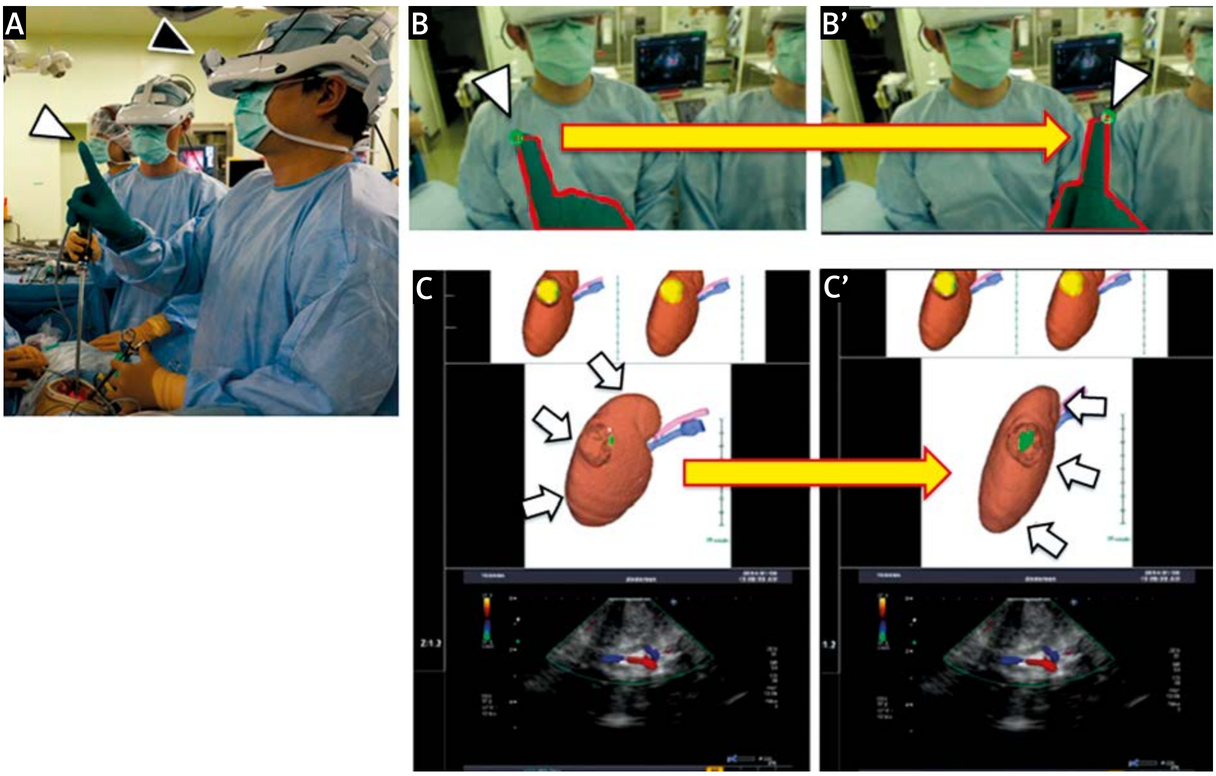

Photo 2. Rotation of the 3D video image according to the operator's fingertip movement. **A** – Video camera (black arrow head) was mounted to track the operator's index finger (arrow head). The operator moved their fingertip (arrow head, yellow arrow) (from **B** to **B'**) to adjust the direction of the 3D video image to the on-site endoscopic view looking at the integrated multiple image in the head-mounted display (from **C** to **C'**)

and intraoperative ultrasound findings. Using the HMD, surgeons can view the multiple images in one view using a split screen, regardless of their head position. Moreover, our novel system may demonstrate further application that the HMD can be used as a multisensory devise. The operator could manipulate the data, such as a 3D video image, with finger-tip movement using the finger tracking system with a video camera mounted on the HMD. The operator can adjust the 3D video image in the direction of the on-site endoscopic view. The HMD integrated image monitoring system allows surgeons to make real-time simulation of the tumor excision easier and facilitate the clampless PN.

The efficacy of the HMD system in gasless single-port clampless PN needs to be carefully evaluated because we have just begun to apply the system to this procedure. However, its potential usefulness is high, and it may help refine radiologic and endoscopic image monitoring. The HMD system may offer potential advantages not only for PN procedures but also for other surgical procedure such as hepatectomy and resection of brain tumors.

Conclusions

We demonstrated the novel application of HMD as an integrated image monitoring system in PN. In this system, all participants were able to wear an HMD and could view shared integrated multiple images. Our experiences show that the integrated image HMD system might facilitate maneuverability and safety during the minimally invasive clampless PN. In addition, this HMD system is compact, easily introduced, and affordable.

Acknowledgments

Kazunori Kihara and Kazutaka Saito contributed equally.

References

1. Russo P. Partial nephrectomy for renal cancer (part II): the impact of renal ischaemia, patient preparation, surgical approaches, management of complications and utilization. BJU Int 2010; 105: 1494-507.
2. Kihara K. Application of gasless laparoendoscopic single port surgery, GasLESS, to partial nephrectomy for renal cell carcinoma: GasLESS-clampless partial nephrectomy as a multiply satisfactory method. Int J Urol 2012; 19: 3-4.
3. Komai Y, Sakai Y, Gotohda N, et al. A novel 3-dimensional image analysis system for case-specific kidney anatomy and surgical simulation to facilitate clampless partial nephrectomy. Urology 2012; 83: 500-6.
4. Kihara K, Fujii Y, Masuda H, et al. New three-dimensional head-mounted display system, TMDU-S-3D system, for minimally invasive surgery application: procedures for gasless single-port radical nephrectomy. Int J Urol 2012; 19: 886-9.
5. Kihara K, Koga F, Masuda H, et al. Feasibility of gasless single-port clampless partial nephrectomy for peripheral renal tumor: an experience of 118 consecutive cases. Eur Urol Suppl. 2012; 11: 1 (E143).
6. Kihara K, Koga F, Masuda H, et al. Gasless single-port clampless partial nephrectomy for peripheral renal tumor: surgical, short-term oncological, and functional outcomes. J Urol 2012; 187: 4 (E448).
7. Kihara K, Tsushima T, Kawakami S, et al. Gasless single port access ultrasound-guided clampless partial nephrectomy: MIES partial nephrectomy. Eur Urol Suppl 2010; 9: 335-6.
8. Yoshida S, Kihara K, Takeshita H, et al. Head-mounted display for personal integrated-image monitoring system: ureteral stent placement. Urol Int in press.
9. Yoshida S, Kihara K, Takeshita H, Fujii Y. A head-mounted display-based personal integrated-image monitoring system for transurethral resection of the prostate. Videosurgery Miniinv in press.
10. Yoshida S, Kihara K, Takeshita H, Fujii Y. Instructive head-mounted display system: pointing device using a vision-based finger tracking technique applied to surgical education. Videosurgery Miniinv in press.

Received: 25.03.2014, **accepted:** 28.03.2014.