

A New Concept for a “Vaginal Hysterectomy” Robot

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Abstract. The design concept of a novel vaginal hysterectomy robot which is composed of three compound robots is discussed. The results of *in vitro* mechanical evaluation of the first two prototypes are reported and ideas for future development discussed.

Keywords: Surgical robot; Medical robot; Hysterectomy robot.

1 Introduction

Nowadays, the Da Vinci surgical system, approved by the FDA in September 2001, is the state-of-the-art surgical technology [1]. Its disadvantages are its higher costs and longer operating room times [2]. In addition, none of the existing robotic systems are equipped to provide high quality feedback; this is of major concern as errors can have potentially devastating consequences [3].

Many different types of small task specific medical robots are currently being developed in many institutes. For example, a robot that provides assisted motion for knee and shoulder joints is gaining wide acceptance [4]. A robot-controlled fluid system was introduced to detect *ex vivo* breast cancer chemotherapy sensitivity [5].

In surgery, the SpineAssist robot has shown a high level of accuracy *in vivo* for the implantation of lumbar pedicle screws [6]. A dexterous miniature robot for natural orifice transluminal endoscopic surgery has been tested in multiple animal model studies [7] and also been performed successfully in humans, including appendectomy and cholecystectomy [8-10].

Hysterectomy is the most common non-pregnancy-related surgery, with approximately 600,000 procedures performed annually in the USA [11]. Vaginal hysterectomy, a natural orifice procedure, has been reported as a standard hysterectomy which the advantage of less pain and rapid recovery [12]. However, before performing this procedure a new surgeon needs a period of learning from an expert. In order to simplify this procedure we have designed a prototype of a compound multiple simultaneous vaginal hysterectomy robot and subjected it to mechanical tests. Once perfected, we hope this robot could help the young gynecologists to perform vaginal hysterectomies with the same speed and success rate achieved by an expert.

2 Design concept and procedure

The compound vaginal hysterectomy robot is composed of three small robots working simultaneously; ligaments and vessels cutting, uterine bisecting and vaginal cuff sealing robots. The mechanical joints were located in a common body with motions controlled by external moving slings.

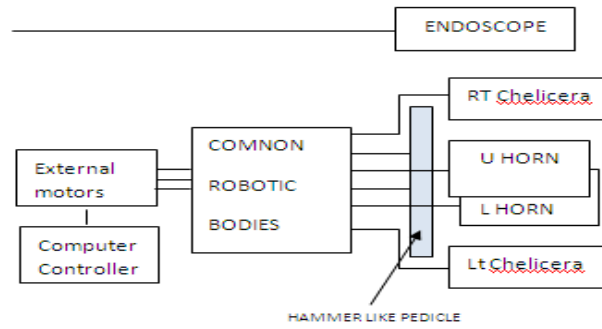


Fig.1.Diagram showed a compound vaginal hysterectomy robot

2.1 Ligaments and vessels cutting robot

In the first scorpion-like robot, the right and left chelicerae could move with two DOFs diving by two sling sheaths. The robot was able to grip and manipulate the uterine suspensory ligaments and vessels at the parametrium to free the uterus from human cavity.



Fig.2. The right and left chelicerae of the scorpion-like robot were able to grip and manipulate the ligaments and vessels at parametrium. (black arrow)

2.2 Uterine Bisecting Robot

A Dynastes Hercules-like robot was designed to manipulate the uterus, working simultaneously with the first robot. It could move its [upper](#) and [lower](#) horns (two DOFs) by opening and closing their joint.

During the large uterine operation this robot could bisect the large uterus with a cutting saw. Each horn was composed of an inner longitudinal groove containing a movable saw. The saw is moved by a power sling and sheath from an external motor. It saws the uterus into two smaller pieces which can then be easily removed through the vaginal canal

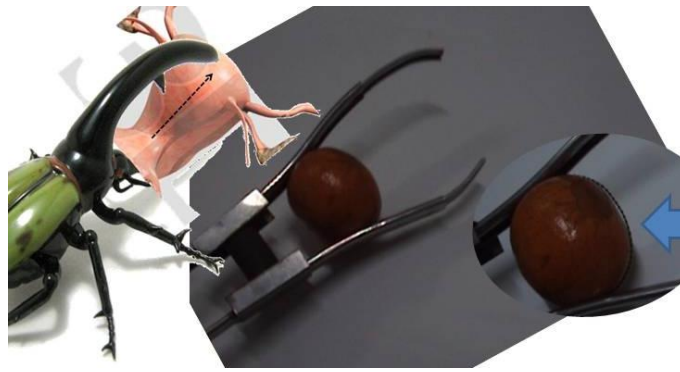


Fig.3. A *Dynastes Hercules*-like robot was designed to manipulate and cut the uterus simultaneously with the work of the first robot. During the large uterine operation this robot can bisect the uterus using a cutting saw inside the sulcus. (arrow)

2.3 Vaginal cuff sealing robot

This is a robot with two hammer-like pedicles, containing suture material. It could work automatically after the start of the process. We plan to produce a first prototype in the near future.



Fig.4. Vaginal cuff sealing robot.

3 Experiments

The tests occurred in October 2011 in Khon Kaen University, Thailand. The purpose was to test the mechanical movement of the first prototypes of the ligaments and vessels cutting and uterine bisecting robots.

3.1 The mechanical test of the ligaments and vessels cutting robot

Ten pieces of fresh raw meat size $5 \times 5 \times 0.5 \text{ cm}^3$ were used in this experiment. A 3 minute gripping test was performed to compare between the robotic chelicerae and traditional Heaney clamps. The depths of tissue collapse were recorded by visual ruler and the results subject to statistical analysis. Table I shows that there were no statistically significant differences between the results achieved with the two devices.

Table 1. The gripping test compared between the robotic chelicerae and traditional Heaney clamps

Experiment	Gripping test of tissue collapse(mm)		
	<i>The robotic chelicerae</i>	<i>Traditional Heaney clamps</i>	<i>p.</i>
1	2	3	> .05
2	3	3	
3	3	3	
4	3	2	
5	2	2	
6	3	3	
7	3	3	
8	3	3	
9	2	3	
10	2	2	

No statistical difference by Wilcoxon Signed Rank test*

3.2 The mechanical test of the uterine bisecting robot

The mechanical bisecting experiment was performed using apple fruit as the specimens. In three experiments, one achieved complete bisection of the fruit while the other two trials resulted only in partial bisections of the apples. The problems were caused by instability of the sling motion and the lack of stability of the specimens during the cutting process.

4 Discussion

Nowadays, the new technology using robotic surgery and other automated devices, is gradually penetrating our practice. The steps of development of the surgical robots could be divided into three essential stages.

The first stage is “Robot assisted human surgeries”. The DaVinci Model is already on the market and shows many benefits in assisting surgeries. The next models, which are now being developed in many laboratories around the world will be quite small in size and have a quick set-up time. However, these robots still need human to operate in the external console, their operators require considerable training to use them, and they are still expensive.

The second stage is “Human assisted robotic surgery”. The surgical procedures for the robots need to be simplified so that the robot could easily operate under human guidance. The vaginal hysterectomy robot being developed in our laboratory is small sized and designed specifically for this type of operation. The surgeon should be able to control the robot simply by giving permission for each of operating steps. After it is completely developed, the robot could help young gynecologists to operate as if they are experienced experts. In addition, they might do the vaginal hysterectomy in less than 30 minutes.

The last stage will be “Real robotic surgery”. The robots will be able to perform the operation with limited or even no human control. In this stage the major development trends will be; 1) miniaturization and augmented reality [13, 14], 2) automation [15] and 3) no theatre operation or remote controlled telesurgery.

5 Future work

In further work, the prototype of the third robot will be produced. Then, the first and second robots will be combined with it to investigate the compound device's functioning and control system. Finally, we hope to develop the vaginal hysterectomy robot so as to miniaturize it. We also hope to give it augmented reality and create a semiautomatic robot.

6 Conclusion

In this paper, we reported our tests of two prototypes of a vaginal hysterectomy robot which are designed to perform the procedures of the traditional vaginal hysterectomy. The experiments showed no difference in gripping power between traditional method and robotic power. However, the bisection processes need to be revised and re-evaluated.

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