論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Development of a Trocar Insertion Device for Laparoscopic Surgery
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11187号, 授与年月日:2019年3月26日, 学位の種別:課程博士, 審査員:只野 耕太郎,小俣 透,初澤 毅,中村 健太郎,石田 忠
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11187号, Conferred date:2019/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	ﾗｲﾌｴﾝｼﾞﾆｱﾘﾝｸﾞ 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 (工学) Doctor of
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In this research a novel trocar insertion device for laparoscopic surgery is developed. This trocar insertion device integrates functions of lifting up the abdominal wall and driving trocar insertion, which enables one surgeon to operate by himself or herself. In addition, this device recognizes the abdominal penetrate-out by monitoring the change of insertion force. It enables a person even without experience to achieve safe trocar insertion easily.

In the first chapter, the fact is introduced that majority of surgical injuries caused by overshooting occur during the initial trocar insertion in laparoscopic surgery. Under this background, some researches have been carried out to improve the design of trocar products, and other researchers focus on developing a trocar insertion training system. However, there are still defects in aspects of easy operation, safety and automation. Therefore, developing an easy-operated trocar insertion device, which is safe and can be used by people even without any experience, has been established as the purpose of this research.

In the second chapter, insertion force by different trocars are measured using a porcine abdominal wall. The magnitude of insertion force differs from many factors, such as types of trocars, insertion speed and insertion method, but all experiments have similar overall profile of insertion force, that there are three peaks obviously in the whole process of insertion and the second peak is the largest one. Based on abdominal multilayers structure and the theory of the force peak's occurrence, it is clarified that the profile of insertion force reflects the abdominal multilayers structure. Technically the small peak next to the largest one reflects the penetrate-out of the abdominal wall. In engineering, the largest force peak (the second one) is regarded as a reminder to help computers recognize penetrate-out. Besides that, the influence of factors (insertion speed, insertion method, trocar types) on the insertion force are discussed

in this chapter. It proves that insertion with a sharper trocar, at a higher insertion speed, and with rotation can decrease the insertion force at a certain level.

In the third chapter, based on the measurement of insertion force, an easy-handheld device is designed. Its actuators consist of vacuum suction cups, pneumatic cylinders and DC motors. With the method of cupping, vacuum suction cups are used to adhere the device onto the abdominal wall. Under a high stiffness impedance control, the pneumatic cylinders play a role of lifting up the abdominal wall to make it stable as the assistant surgeon holds up. And two DC motors drive the trocar to insert forward with rotation. Instead of using force sensor, air driving force in cylinder's impedance control is monitored to recognize force peaks. In addition, the improved device takes the form of assembly of components (trocar relating parts, device body and suction cup relating parts) to make it possible for adapting to different trocars and sterilization in clinical application. Lastly, *Exvivo* experiments using porcine abdominal wall are conducted. Even though the automatic stop algorithm for safe insertion has not been added up, it has proved that this device can successfully insert a trocar while lifting up the abdominal wall and force monitoring method by pneumatic cylinders can obviously sense the force peaks during insertion.

In the fourth chapter, based on the insertion force characteristics introduced in chapter 2 and the trocar insertion device designed in chapter 3, an automatic stop algorithm has been programed for this device system. When the force monitor of pneumatic cylinders under high stiffness impedance control detects the second force peak during insertion, the device discontinues the insertion automatically and immediately. It accesses a novice to achieve safe insertion by just pressing a button. *Exvivo* experiments using the porcine abdominal wall are conducted to verify its effectiveness. Results show insertion by this device can discontinue insertion immediately upon the trocar penetrates out of the abdominal wall. After the trocar stops, the exposure length is approximately 5-10 mm, which is considerably shorter than the average length (~90 mm) of human beings between bottom layer of the abdominal wall and organs or arteries.

Three innovations of this research can be concluded as follows:

1. The relationship between trocar overall profile of insertion force and abdominal multilayers

structure was explained.

2. A novel trocar insertion device has been developed. Using components like suction cup, pneumatic cylinders, DC motors, it integrated two functions of lifting up the abdominal wall and driving trocar insertion.

3. Without force sensors, this device was able to recognize the abdominal penetrate-out by monitoring driving force of the pneumatic cylinders indirectly.