Thermo-Visual Evaluations of Acute Abdomen Pain in Children

Aleck Ovechkin, Kyeong-Seop Kim, Jeong-Whan Lee and Sang-Min Lee

Abstract - About two thirds of patients admitted to hospitals world-wide suffer from acute abdomen pains of varying degrees of severity. Acute abdomen pain due to appendicitis or pancreatitis usually requires urgent surgical treatment, whereas pain due to heart ischemia or enteroviral infection requires only drug treatment. In general, making an immediate decision about whether or not acute abdomen pain requires urgent surgery is very difficult. This decision becomes even more difficult when the patient is a young child who can't properly describe the abdominal pain. In this case, thermo-visual inspection can alternatively be used to decide whether urgent surgical treatment is necessary to cure the abdominal pain.
Keywords - acute abdomen pain, thermo-visual, hyperthermia, hypothermia, sensitivity, specificity

1. Introduction

To determine the necessity of surgery for a patient suffering from acute abdomen pain, the patient's blood and urine samples must usually be analyzed or the patient's internal organs must be examined invasively. If a patient's health condition is poor, the invasive diagnostic method is difficult to use. In this case, thermo-visual inspection by an infrared camera system can alternatively be used to determine the necessity of surgical treatment for acute abdomen pain. In fact, thermo-visual diagnosis is an absolutely harmless, passive, and non-invasive method to locate the origin of acute abdomen pain.

Thermo-visual inspection requires only three to five minutes to scan a patient and requires no special preparation prior to examination. So far, thermo-visual inspection has been applied to supplementary clinical decisions [1~6], medical treatment control [7], urgent pathology [8~10], breast cancer diagnosis [11~14], and even traditional Chinese medicine [15]. Our study is the first attempt to use the thermo-visual method to diagnose an origin and the degree of severity of abdominal pain.

2. Clinical Thermo-Visual Inspections of Acute Abdomen Pain

The clinical works presented here were made from 1991 to 1998 at the Regional Hospital of Birobizhan (Jewish Region, Russia), the Republic Childrens Hospital of Ioshkar-Ola (Mari-El Republic, Russia), the Meschersky Medical Center, and the Regional Diagnostic Center (Nizhni Novgorod, Russia). Some parts of the clinical data were acquired from Puls Medical Center in Varna, Bulgaria, and the Biocontrol Diagnostic Center in Cosenza, Italy. From 1991 to 1998, more than 15,000 patients were clinically examined. Among them, 4,785 patients aged 1 year to 16 years (34.8% boys and 65.2% girls) were selected for thermo-visual evaluations. The selected patient group's age distribution is shown in Table 1. All of the selected patients were admitted to one of the mentioned hospitals and complained of acute pain in their abdomens. Table 2 shows the distribution of diagnosis at the moment of their hosptalizations.

Thermo-visual examination is performed by a thermal imaging system operating in a long infrared spectrum region. This system measures infrared energy dissipated by a patient and maps heat energy into the temperature values. Our thermal imaging system, "TV-03K," has an infrared sensor that is the most sensitive to 10μm long wavelength infrared energy. Infrared radiation emanating from a patient goes into the sensor by condensing infrared waves through the optical lens. The electronic circuit system measures the intensity of the infrared wave and maps it to the proportional temperature value. Fig. 1 shows a schematic diagram of the TV-03K, and Table 3 lists its hardware specifications.

Table 1 The age distribution of 4,785 patients

Age	<1	1~2	3~5	6~8	9~11	12~16
Number of patients	372	551	806	1390	1,077	589
Percentage	7.7	11.5	16.8	29	22.5	12.3

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Table 2 Initial diagnostics at the moment of hospitalization

Diagnosis	Number of patients	Percentage
Acute abdomen pain	2,216	46.31
Appendicitis	1,008	21.06
Diseases of hepato-biliary system (cholecystitis, cholelitiasis, diskinesia of the biliar ducts)	807	16.87
Pancreatitis	81	1.69
Intestinal diseases (colitis, intestinal disbacteriosis)	195	4.08
Gastritis, stomach/duodenal ulcer	360	7.52
Other diseases and conditions	118	2.47
Total	4,785	100

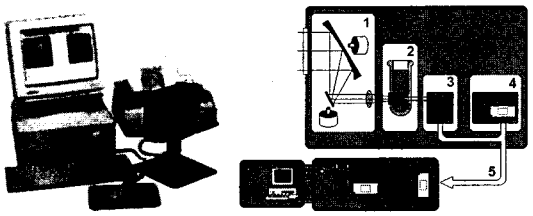

Fig. 1 The TV-03K thermal imaging system

and its schematic diagram: 1. Scanning system consisting of two mirrors, condensed lens, and two motors to adjust the mirrors; 2. Infrared sensor; 3. Analog amplifier and noise reduction circuit; 4. Motor controller unit; 5. Communication cable; 6. ISA card with ADC, DAC, power supply, and communication unit; 7. Display unit.

Table 3 Hardware specifications of the TV-03K

Absolute temperature resolution	0.05℃
Relative temperature resolution	0.002℃
Cooling type	Liquid Nitrogen
Infrared sensor	Single CdHgTe diode
Acquisition speed	1 frame per 2 seconds

In fact, the thermal imaging system is a non-contact, passive device since it only receives infrared emissions radiated from patients and converts these values into thermal intensity. When the intensities are displayed on the computer screen or printed, they are called a thermogram [16]. A thermogram is a map of thermal energy into a pseudo-colored image using the standard palette of colors where reds or yellows indicate high temperatures and blues represent low temperatures. In black-and-white mode, brightness indicates higher temperature. Since a thermogram can display the temperature distributions over wide skin area in real time, it can show both the functional activities and pathological changes of the human body at once. Thermo-visual examinations were performed just after hospitalization of the patients and before any diagnostic device or treatment was applied. Once thermo-visual examinations were applied, a preliminary diagnosis was made. If necessary, the patient was given additional thermo-visual inspections.

3. Thermo-Visual Evaluations of Acute Abdomen Symptoms

If a temperature gradient between a reference area and a pathologically changed area is within ±0.8°C, we consider this temperature difference a normal physiological temperature gradient. But if the temperature difference is higher than 1°C (typically 1.2°C~1.8°C), we consider the patient's pathological condition crucially changed from a normal condition and observe the size of the hyperthermic areas and their locations.

For normal acute abdomen pain conditions, thermograms reveal symmetrical temperature distributions on an abdominal wall. In this case, an umbilicus may visible as a small hyperthermic spot. In some cases (especially for a skinny patient), we can see a small sized hyperthermia with a temperature gradient up to 0.4°C above the lower ribs and in iliac areas. Fig. 2 shows a normal acute abdomen pain condition.

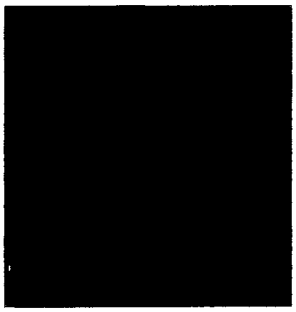

Fig. 2 Thermogram of a child with a normal condition from acute abdomen pain

The brief descriptions and illustrations of thermo-visual diagnoses of the cause of acute abdomen pain are described in the following sections.

3.1 Appendicitis

In acute abdomen pain caused by appendicitis, the hyperthermic area usually appears above the appendix or on the right inguinal side (see Fig. 3). In this figure, the hyperthermic spot is denoted with an arrow to enhance visuality. This hyperthermia is visible one or two hours after the initial stage of the disease. This initial hyperthermia retains its shape for a day. After that, thse hyperthermal area becomes larger due to the spreading of inflammation and the formation of peritonitis. The temperature difference between the center of hyperthermal area and the symmetrical body area ranges from 1.2°C to 3°C.

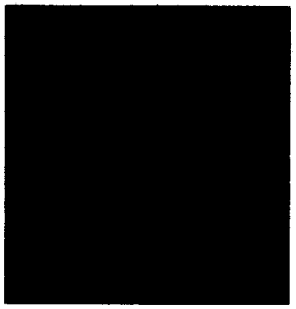

Fig. 3 Hyperthermia on the right inguinal area indicating appendicitis

3.2 Pancreatitis

For acute abdomen pain caused by pancreatitis, hyperthermia appears above the pancreas (see Fig. 4). The shape of the hyperthermal area is often similar to the organ's form. The temperature difference between the area of hyperthermia and the surrounding area usually ranges from 1°C to 1.8°C.

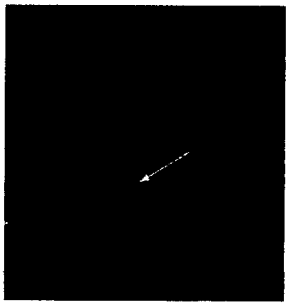

Fig. 4 Hyperthermia due to pancreatitis

3.3 Cholecystitis

For acute abdomen pain caused by cholecystitis, a hyperthermic area is round and usually appears above the gallbladder (see Fig. 5). When the gallbladder contains no stone, the contrast pattern of hyperthermia is usually homogenous. Hyperthermia appearing as a spotted contrast pattern above the gallbladder usually indicates the presence of stones. Making a conclusion about the presence of stones by merely examining the thermograms is sometimes difficult.

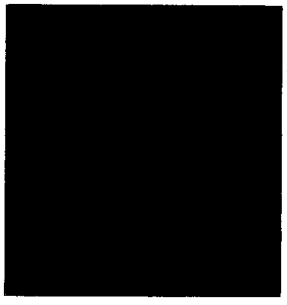

Fig. 5 Hyperthermia above a gallbladder in the case of non-calculus cholecystitis

3.4 Gastritis

For acute abdomen pain caused by gastritis and gastroduodenitis with a high secretion, hyperthermia appeares at the front wall of abdomen. The contrast pattern of the hyperthermia is usually inhomogenous and spotted. Sometimes it has the shape of a stomach (see Fig. 6). For gastritis with a low secretion, the cold spots, i.e., hypothermic areas (hypothermia), can appear above the stomach (see Fig. 7).

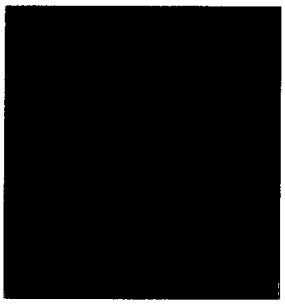

Fig. 6 Hyperthermia on a stomach area in the case of gastritis with high secretion

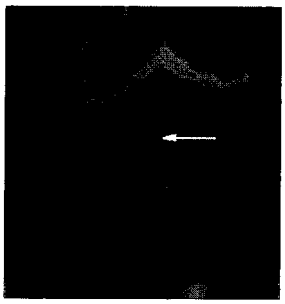

Fig. 7 Hypothermia on an epigastral area in the case of gastritis with low secretion

3.5 Intestinal obstruction

With intestinal obstruction, a hyperthermal area with a round shape is observed (see Fig. 8). Sometimes a hypothermic area is visible below the heart.

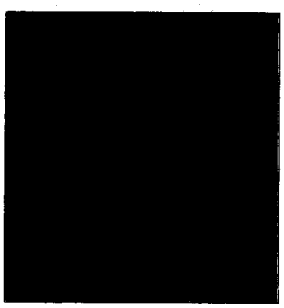

Fig. 8 Hyperthermia due to the obstruction of a sigmoid colon

3.6 Hernia of abdomen wall

With an abdomen wall's hernia, a hypothermic area is bordered with hyperthermia. An umbilical hernia surrounded by a hyperthermal ring is often visible (see Fig. 9).

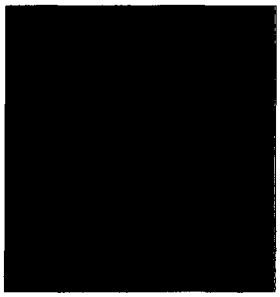

Fig. 9 Hyperthermal ring pattern around an umbilical hernia

3.7 Diskitis of the biliary ducts

The thermo-visual manifestation of spastic diskitis of the biliar ducts is a hyperthermal area on the umbilicus (see Fig. 10). Due to the additive inflammation and the formation of cholecystocholangitis, a smooth and spotted hyperthermal area often appears above the liver. For hypotonic diskitis of the biliar ducts, hypothermia is visible at the left hypochondria.

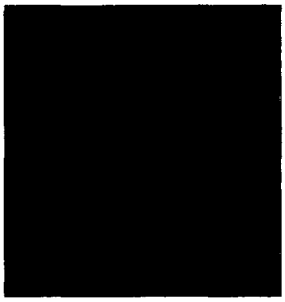

Fig. 10 Hyperthermia on an umbilicus indicating biliar duct's spastic diskinesia

3.8 Colitis

A thermo-visual sign of colitis is the occurence of hypothermal spots below and to the side of the umbilicus

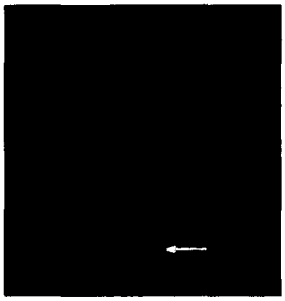

Fig. 11 Hypothermia on the lower abdomen in the case of spastic colitis

(see Fig. 11). In general, the size of the hypothermal spots are related to the degree of severity of the disease.

3.9 Viral hepatitis

Acute abdomen pain caused by viral hepatitis is indicated by a hyperthermia above the liver on the day of infection (see Fig. 12). Sometimes the hyperthermic area has a homogenous structure, and it is always related to the rate of biochemical changes in the blood.

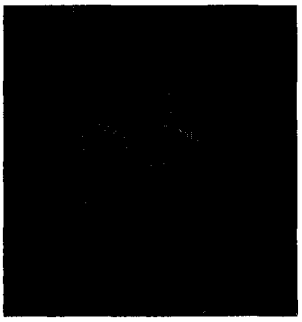

Fig. 12 Hyperthermia above the liver indicating viral hepatitis

3.10 Enteroviral infections

Acute abdomen pain caused by enteroviral infection, a thermogramm usually shows no abnormal heat pattern. If the syndrome is caused by severe intoxication, a hypothermic area can be found above the liver or pancreas (see Fig. 13).

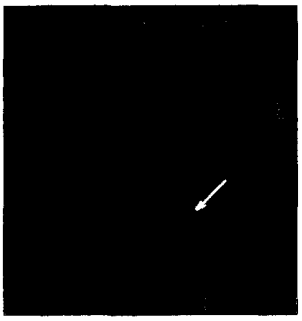

Fig. 13 Hypothermia above the pancreas in the case of enteroviral infection

4. Results

The effectiveness of thermo-visual diagnosis on acute abdomen pain was estimated by comparing its results with those from conventional clinic tests such as anamnesis, inspection, blood and urine analysis, and ultrasound examination. The following performance indexes are used to estimate the diagnostic capabilities of the thermo-visual method:

Sensitivity (S_N) = $T_P \cdot 100/(T_P+F_N)$ %,

Specificity (S_P) = $T_N \cdot 100 / (T_N + F_P)$ %,

Prognosis Precision (P_P) =

$(T_N + T_P) \cdot 100 / (T_P + T_N + F_N + F_P)$ %

where T_P is the count of true positive results, T_N is the count of true negative results, F_N is the counts of false negative results, and F_P is the count of false positive results.

Table 4 shows the summarized results of conventional clinic tests and the thermo-visual method. It also shows that the sensitivity of the conventional clinic tests for diagnosing acute appendicitis, cholecystitis, diskinesia of the biliar ducts, enteroviral infection, and viral hepatitis ranges from 48% to 63%. On the contrary, the sensitivity of the thermo-visual method for diagnosing the same syndrome ranges from 93% to 99%.

Table 4 Performance indexes of the conventional clinic and thermo-visual diagnoses of acute abdomen pain

Diagnosis	Number of patient	Clinical diagnosis*		Thermo-visual diagnosis	
		S_p (%)	S_n (%)	S_p (%)	S_n (%)
Acute appendicitis	672	61.3	80.1	99.89	99.8
Acute pancreatitis	24	75.0	99.7	83.33	99.8
Cholelithiasis	18	72.2	99.7	72.22	99.9
Cholecystitis	279	58.7	97.9	89.96	99.5
Intestinal obstruction	76	51.3	99.7	81.58	99.9
Stomach and Duodenal ulcer	32	53.1	99.5	78.13	99.9
Hernias of abdomen wall	115	91.3	99.9	87.83	100
Diskinesia of the biliar ducts	1,636	48.5	84.9	94.56	94.6
Colitis, intestinal disbacteriosis	563	71.5	99.1	93.07	99.8
Enteroviral infection	570	50.3	97.8	97.54	99.9
Gastritis	715	84.2	92.8	97.06	99.6
Viral hepatitis	33	63.6	99.7	93.94	99.9
Other diseases	52	46.1	99.7	92.31	99.9

* Clinical diagnosis consists of a doctor's inspection, blood and urine analysis, ultrasound examination, and gastroscopia.

When a patient is admitted to a hospital, a doctor must make an urgent decision about the necessity of surgery. Thermo-visual diagnosis can be used to classify the severity of acute abdomen pain into two categories: surgical or therapeutical. The surgical group consistes of those suffering acute abdomen pain that must be treated by the appropriate surgical operation. The pain caused by acute appendicitis, intestinal obstruction, or ulcer bleeding is falls into the surgical group. The therapeutical group consists of those suffering abdomen pain that can be treated by drugs. The pain caused by diskinesia of the biliar ducts, spastic colitis, and viral hepatitis is categorized into this group. Table 5 shows the comparative results of conventional clinic diagnosis with thermo-visual evaluations for classifying acute abdomen pain as surgical or therapeutical.

Table 5 Summarized analysis of conventional clinic and thermo-visual diagnosis on acute abdomen pain in a nosological group

Nosologi-cal group	Number of patient	Clinical diagnosis*			Thermo-visual diagnosis		
		S_n %	S_p%	P_P%	S_n%	S_p%	P_P%
Surgical	937	64	77	74	95	99	98
Thera-peutical	3,848	59	13	50	94	75	91
Total	4,785	60	-	21	94	-	89

* Clinical diagnosis consists of a doctor's inspection, blood and urine analysis, ultrasound examination, and gastroscopia.

5. Discussion

Based on our observations of conventional clinic tests and thermo-visual diagnosis, we can conclude that the thermo-visual method is a very effective alternative method for determining the cause of acute abdomen pain in children. The performance indexes (sensitivity, specificity, and prognosis precision) show that thermo-visual diagnosis of the cause of acute abdomen pain is more efficient than standard clinical methods. Hence the thermo-visual method can assist doctors in making a quick decision regarding the need for surgery.

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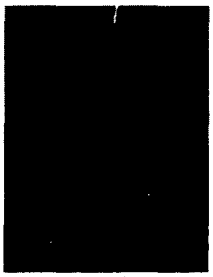

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