

Diagnostic Imaging Utilization in Cases of Acute Appendicitis: Multi-Center Experience

Appendix

1. Organization of LOCAT (Low-dOse CT Appendicitis Trial) group

1.1. LOCAT office

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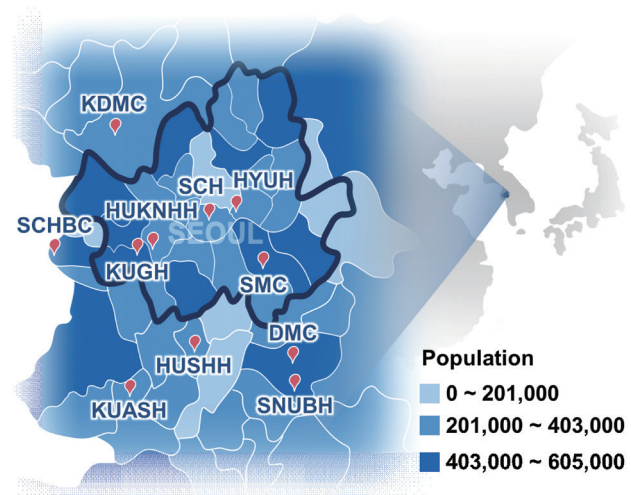
1.2. Investigating sites

The LOCAT office sent out a letter to all members of the Korean Society of Abdominal Radiology (a nationwide society of abdominal radiologists) from 119 hospitals in Korea (including 67 in metropolitan Seoul [Seoul and Gyeonggi]) to invite them to participate in this study. The initial requisites for study participation stated in the invitation were: (a) at least 50 non-incident appendectomies had been performed annually in recent years, and (b) multidisciplinary services were provided for patients with suspected appendicitis 24 hours per day, seven days per week. As only 2 of 27 hospitals which responded to the invitation were located outside metropolitan Seoul, we decided to limit the study region to metropolitan Seoul with a total population of 21 million (1) and where 40,000 appendectomies were performed in 2011 (2). We then sent a second letter to the 25 hospitals in metropolitan Seoul to inform them of additional requisites for study participation and to solicit information regarding their practice patterns. Eleven hospitals responded to the second letter and participated in the study (Appendix Table 1, Appendix Fig. 1). They were eight tertiary and three secondary hospitals with a median bed number of 800 (range, 554-1950), accounting for 18% of the 63 hospitals having 300 or more beds and 26% of 42 hospitals having 500 or more beds in metropolitan Seoul in 2011 (3).

Appendix Table 1. Number of beds and study patients per site

Site	Beds, No.	Patients Included in the Study, No.
Overall	9,557	2,321
Site 1	689	667*
Site 2	561	290
Site 3	800	244
Site 4	554	230
Site 5	900	229 [†]
Site 6	749	166
Site 7	1,034	142
Site 8	1,950	130
Site 9	920	105
Site 10	840	71
Site 11	560	47

*Includes 320 patients included in another study (4); [†]Includes three patients included in another study (5).



Appendix Fig. 1. Locations of the 11 sites. DMC indicates Daejin Medical Center (Bundang Jesaeng General Hospital); HUSHH, Hallym University Sacred Heart Hospital; HUKNHH, Hallym University Kangnam Sacred Heart Hospital; HYUH, Hanyang University Medical Center; KUASH, Korea University Ansan Hospital; KUGH, Korea University Guro Hospital; KDMC, Kwandong University College of Medicine; SMC, Samsung Medical Center; SNUBH, Seoul National University Bundang Hospital; SCHBC, Soonchunhyang University Bucheon Hospital; SCH, Soonchunhyang University Hospital.

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- Grant #02-2014-053 from Seoul National University Bundang Hospital.

2. Questionnaires for investigating sites

The purpose of the questionnaires was to inform the site principal investigator (PI) of the requisites for study participation and to solicit information regarding practice patterns at the site. The questionnaires included the following: (2.1. Site Information, 2.2. Requisites for study participation, and 2.3. Pattern of Patient Care).

2.1. Site Information

- Hospital name
- Hospital address
- Name of site principal investigator (PI)
- Signature of site PI
- Number of beds in the hospital
- Annual number of appendectomies in recent years

2.2. Requisites for study participation

The site PI understands that the site can participate in the study only when the site meets all the following requisites:

- At least 50 non-incident appendectomies have been performed annually in recent years.
- Multidisciplinary services were provided for patients with suspected appendicitis 24 hours per day, seven days per week during the study period.
- The site PI should identify all patients who visited the emergency department and then underwent non-incident appendectomies during the study period.
- The study coordinators and research associates should be privileged by relevant authorities, including the site Institutional Review Board, to review the medical records of the study patients.
- The site PI should allocate adequate time and space for data collection, and allow study coordinators and their assistants access to all study-related documents and facilities.
- The site PI should provide the numbers and experience levels of physicians, radiologists, surgeons, and pathologists involved in the care of the patients.
- The site PI should provide the CT parameters and typical effective radiation dose used to examine the patients.
- There should be clear documentation of the presence or absence of appendicitis in pathology reports in the patients.
- In cases with pathology reports inconclusive for the presence of appendicitis, a site pathologist should re-examine the primary tissue sections.

2.3. Pattern of Patient Care

From each site, we solicited information on the patterns of patient care, including the doctors involved in patient care, initial clinical evaluation in the emergency department, determination of the need for imaging examination(s), CT machines and imaging parameters, typical effective radiation dose of CT examinations, interpretation of imaging test(s), surgical plan, and discharge and follow-up protocol. In addition to the questionnaires, two or more interview sessions with site investigators were conducted for each site. The interviewees included, but were not limited to, an emergency department physician, a radiologist, a surgeon, a pathologist, and a radiology technologist who played major roles in patient care. The questions included:

- Who initially evaluated patients with suspected appendicitis in the emergency department? Choose one or more from residents,

fellows, attending physicians, or other (describe).

- Who supervised the clinical evaluation in the emergency department? Choose one or more from residents, fellows, attending physicians, or other (describe).
- Who determined the need for imaging test(s)? Choose one or more from emergency department residents, emergency department fellows, emergency department attending physicians, surgical residents, surgical fellows, attending surgeons, or other (describe).
- Detail the CT imaging parameters.
- What was the typical effective radiation dose of a CT scan for an average-sized patient, based on dose reports from CT machines?
- Detail the ultrasonography procedure. Who performed the ultrasonography?
- Who interpreted the CT and ultrasonography for the patients during working hours? Choose one or more from radiology residents, fellows, attending radiologists, or other (describe).
- Who interpreted the CT and ultrasonography performed after hours? Choose one or more from radiology residents, fellows, attending radiologists, or other (describe).
- When were the on-call radiologists' preliminary reports verified by attending abdominal or emergency radiologists?
- If the attending abdominal or emergency radiologists made any important changes to the preliminary report, did they immediately notify the referring physicians or surgeons so that the patient management could be changed?
- Which surgeon first evaluated the patient? Choose one or more from surgical residents, surgical fellows, attending surgeons, or other (describe).
- What general policy did the surgeons have in determining the surgical plan, discharge, and follow-up?

3. Categorization of CT and ultrasonography reports

The study coordinators retrospectively categorized the CT and ultrasonography reports using a 3-point scale for the diagnosis of appendicitis using the criteria in Appendix Table 2.

Appendix Table 2. Categorization of CT and ultrasonography reports for the presence of appendicitis

Grades	Details
Grade 1. Appendicitis absent	Definite conclusion of the absence of appendicitis, or conclusion of the absence of appendicitis with a likelihood modifier such as 'possibly not', 'probably not', 'less likely' and 'unlikely'
Grade 2. Indeterminate	Direct statement of equivocality of the diagnosis, or an equivalent probability of appendicitis and other diseases
Grade 3. Appendicitis present	Definite conclusion of the presence of appendicitis, or conclusion of the presence of appendicitis with a likelihood modifier such as 'possibly', 'probably' and 'likely'

CT, computed tomography.

4. General pattern of patient care

4.1. Doctors involved in patient care

The numbers and experience of attending and trainee doctors involved in patient care are provided in Appendix Table 3.

4.2. Clinical suspicion of appendicitis

Because of the high prevalence of appendicitis, many physicians having different experience levels were involved in the clinical evaluation (4.1. Doctors involved in patient care). Typically, patients were initially evaluated by one of the emergency department physicians, including attending physicians, fellows, and residents. Each of them, under the supervision of one of the attending physicians, performed history-taking and physical examination, determined the need and timing of diagnostic tests including imaging studies, contacted radiologists or surgeons for a consultative discussion, and determined the timing of hospital discharge.

4.3. Need for imaging test(s)

The need for imaging or other diagnostic tests was individualized for the patient at the discretion of the emergency department physicians in service.

Appendix Table 3. Doctors involved in patient care

Doctors	Department			
	Emergency medicine	Radiology*	Surgery†	Pathology‡
Attending	44 (3)	33 (2)	80 (7)	54 (4)
Experience after board certification (yr)				
< 5	14 (1)	3 (0)	12 (1)	9 (1)
5-10	19 (2)	8 (1)	27 (2)	12 (0)
≥ 11	11 (1)	22 (2)	41 (5)	33 (2)
Fellow	17 (1)	8 (1)	19 (2)	-
Resident	81 (7)	76 (6)	-	-
1-yr	24 (2)	14 (1)	-	-
2-yr	21 (2)	27 (2)	-	-
3-yr	19 (2)	26 (2)	-	-
4-yr	17 (1)	9 (0)	-	-

Data are numbers of doctors. Numbers in parentheses are medians for sites. *Number of radiologists who performed or read the imaging tests for suspected appendicitis. The number of radiology residents includes only those who had duties after hours; †Number of surgeons who supervised the appendectomy; ‡Number of pathologists who verified the pathologic reports.

4.4. CT and ultrasonography techniques

The imaging tests were performed as a part of the daily clinical practice at each site. Modern CT and ultrasonography machines were used at all sites. We did not investigate the machines or imaging techniques used for imaging tests performed at outside hospitals before the patient was transferred to the site emergency departments.

The CT scanners and imaging parameters from the individual sites are summarized in Table 2.

At all sites, ultrasonography examinations were typically performed by attending abdominal radiologists or senior radiology residents during working hours and by on-call radiologists after hours. The on-call radiologists were mostly residents at all sites. At one site (Site 1), more than half of ultrasonography examinations were performed by emergency department physicians. The ultrasonography procedure typically included an evaluation of the abdomen and pelvic organs using a curvilinear transducer and then a thorough examination of the right lower quadrant with graded compression using a high-frequency linear transducer.

4.5. Interpretation of imaging test(s)

The imaging tests were interpreted as a part of daily clinical practice at each site. At all sites during working hours, the CT or ultrasonography reports were made by abdominal or emergency radiologists. Examinations performed after hours were given preliminary reports by on-call residents. Typically, all preliminary reports made by the on-call residents were revised or supplemented by one of the abdominal or emergency radiologists on the morning of the next working day. The referring physician or surgeon was immediately notified of any important changes in the report so that the patient's management could be changed accordingly.

Our analysis included only final reports. We were unable to separately analyze preliminary reports for two reasons. First, it was often unclear whether or not the preliminary report was changed or which part of the preliminary report was revised by the abdominal or emergency radiologists, as many sites did not have a strict policy of keeping the original preliminary report in their Radiology Information Systems. However, it should be noted that the original preliminary report may have been more likely to affect patient disposition with regard to surgery. Second, because of the limited availability of abdominal radiologists around the clock, some of the addendum reports may have been made after patient disposition with regard to surgery. Therefore, the overall diagnostic sensitivities we measured may have been inflated to some extent.

4.6. Surgery

At all sites, patients who potentially needed surgical exploration were referred to the surgical department. One of the surgical residents was typically the first surgeon to evaluate the patient, and the final decision to operate was approved by board-certified surgeons who performed or supervised the surgery. The surgical plan was individualized for each patient as appropriate, including the need for preoperative percutaneous drainage of periappendiceal abscesses and the use of a laparoscopic approach.

4.7. Discharge and follow-up

Typical criteria for hospital discharge following appendectomy were tolerance of a soft-blend meal, safe ambulation, and afebrile status without major complications. The short-term follow-up was generally scheduled around one to two weeks after appendectomy in outpatient clinics for the survey of complication and stitch-out.

5. Imaging utilization rates

Imaging utilization rates for individual sites and overall rates adjusted for clustering by site are available in Appendix Table 4. 9.7% (213/2,203) of the CT examinations and 16% (31/192) of the ultrasonography examinations were performed at outside hospitals before patient transfer to the site emergency departments (Appendix Table 5).

Appendix Table 4. Overall imaging, CT, and ultrasonography utilization rates

Investigating site	Imaging utilization rate, % (95% CI) [Numerator/Denominator]*	CT utilization rate, % (95% CI) [Numerator/Denominator] [†]	Ultrasonography utilization rate, % (95% CI) [Numerator/Denominator] [‡]
Overall (unadjusted)	99.7 (99.4-99.9) [2,315/2,321]	93.1 (92.0-94.1) [2,160/2,321] [§]	6.5 (5.6-7.6) [152/2,321] [§]
Overall (adjusted) [¶]	99.7 (99.4-100.0) [2,315/2,321]	93.4 (91.5-95.2) [2,160/2,321] [§]	6.1 (4.2-8.1) [152/2,321] [§]
Site 1	99.9 (99.2-100) [666/667]	91.0 (88.6-93.1) [607/667]	8.8 (6.8-11.3) [59/667]
Site 2	99.7 (98.1-100) [289/290]	89.7 (85.6-92.9) [260/290]	10.0 (6.8-14.0) [29/290]
Site 3	100 (98.5-100) [244/244]	96.7 (93.6-98.6) [236/244] [§]	2.9 (1.2-5.8) [7/244] [§]
Site 4	100 (98.4-100) [230/230]	98.3 (95.6-99.5) [226/230]	1.7 (0.5-4.4) [4/230]
Site 5	100 (98.4-100) [229/229]	94.3 (90.5-96.9) [216/229]	5.7 (3.1-9.5) [13/229]
Site 6	98 (95-100) [163/166]	94 (89-97) [156/166] [§]	4 (1-8) [6/166] [§]
Site 7	100 (97-100) [142/142]	89 (83-94) [127/142] [§]	10 (6-16) [14/142] [§]
Site 8	100 (97-100) [130/130]	99 (95-100) [128/130]	2 (0-5) [2/130]
Site 9	100 (97-100) [105/105]	92 (86-97) [97/105]	8 (3-14) [8/105]
Site 10	100 (95-100) [71/71]	92 (83-97) [65/71]	9 (3-18) [6/71]
Site 11	98 (89-100) [46/47]	89 (77-97) [42/47]	9 (2-20) [4/47]

*Defined as the percentage of any preoperative cross-sectional imaging utilization for all non-incident appendectomies; [†]Defined as the percentage of use of CT as the initial imaging modality for all non-incident appendectomies; [‡]Defined as the percentage of use of ultrasonography as the initial imaging modality for all non-incident appendectomies; [§]Numerators do not include three cases in which the order of the two imaging tests was unclear; [¶]Adjusted for clustering by site. CT, computed tomography; CI, confidence interval.

Appendix Table 5. Radiology report availability

	Total (n)	Reports available (n)		Reports not available (n)	
		Confirmed appendicitis	Negative appendectomies	Confirmed appendicitis	Negative appendectomies
CT	2,203* (214*)	2,012 (109)	80 (2)	106 (98)	4 (4)
As initial imaging test	2,160* (206)	1,977 (108)	77 (1)	102 (94)	3 (3)
As complementary imaging test	40 (4)	35 (1)	3 (1)	2 (2)	0
Unclear	3 (3)	0	0	2 (2)	1 (1)
Ultrasonography	192 [†] (31)	101 (1)	16 (0)	67 [†] (26)	8 [†] (4)
As initial imaging test	152 [†] (28)	76 (1)	7 (0)	63 [†] (24)	6 [†] (3)
As complementary imaging test	37 (0)	25 (0)	9 (0)	2 (0)	1 (0)
Unclear	3 (3)	0	0	2 (2)	1 (1)

Numbers in parentheses are numbers of CT or ultrasonography examinations performed at outside hospitals. *Includes one case with a missing pathology report; [†]Includes 40 ultrasonographic studies performed by emergency physicians at Site 1. CT, computed tomography.

6. Negative appendectomy rate

Negative appendectomy rates for individual sites and the overall negative appendectomy rate adjusted for clustering by site are available in Appendix Table 6.

7. Appendiceal perforation rate

Appendiceal perforation rates for individual sites and the overall appendiceal perforation rate adjusted for clustering by site are available in Appendix Table 6.

Appendix Table 6. Negative appendectomy rate and appendiceal perforation rate per Site

Site	Negative appendectomy rate, % (95% CI) [Numerator/Denominator]	Appendiceal perforation rate, % (95% CI) [Numerator/Denominator]
Overall (unadjusted)	4.1 (3.3-4.9) [94/2,320]*	31.9 (30.0-33.9) [710/2,226]*
Overall (adjusted) [†]	4.0 (3.0-4.9) [94/2,320]*	31.0 (25.6-36.4) [710/2,226]*
Site 1	4.9 (3.4-6.9) [33/667]	40.2 (36.4-44.2) [255/634]
Site 2	2.4 (1.0-4.9) [7/290]	17.7 (13.4-22.6) [50/283]
Site 3	2.0 (0.7-4.7) [5/244]	23.4 (18.2-29.3) [56/239]
Site 4	3.5 (1.5-6.7) [8/230]	28.4 (22.5-34.8) [63/222]
Site 5	4.8 (2.4-8.4) [11/229]	35.3 (29.0-42.1) [77/218]
Site 6	2 (1-6) [4/165]*	36 (29-44) [58/161]*
Site 7	6 (3-12) [9/142]	34 (26-43) [45/133]
Site 8	4 (1-9) [5/130]	35 (27-44) [44/125]
Site 9	9 (4-16) [9/105]	23 (15-33) [22/96]
Site 10	4 (1-12) [3/71]	35 (24-48) [24/68]
Site 11	0 (0-8) [0/47]	34 (21-49) [16/47]

*Numerators and denominators do not include one case with a missing pathology report; [†]Adjusted for clustering by site. CI, confidence interval.

8. Diagnostic sensitivities of imaging tests

Appendix Table 5 summarizes the availability of radiology reports for the calculation of diagnostic sensitivities. The diagnostic sensitivities of CT and ultrasonography at each step of the imaging work-up are detailed in Fig. 1. The sensitivity was particularly low, even with indeterminate results counted as positives, for initial CT that required complementary ultrasonography (85%; 95% CI, 66%-96%), complementary CT that followed initial ultrasonography (89%; CI, 73%-97%), and complementary ultrasonography that followed initial CT (88%; CI, 69%-97%).

The sensitivities for the individual sites and overall sensitivities adjusted for clustering by site are available in Appendix Table 7.

Subgroup analyses were performed with a threshold of grades ≥ 2 as positive (6, 7). The low diagnostic sensitivity (or high false negative rate) of initial CT was associated with younger age, female gender, and smaller site appendectomy annual volume in the univariable analysis; and with younger age (95.9% vs. 97.3%; AOR, 0.56; 95% CI, 0.33-0.98), female gender (94.3% vs. 98.2%; AOR, 0.31; 95% CI, 0.18-0.54), and smaller site annual appendectomy volume (94.4% vs. 98.2%; AOR, 0.31; 95% CI, 0.15-0.64) in the multivariable analysis (Appendix Table 8).

The diagnostic sensitivity of initial ultrasonography was not significantly affected by any of the factors tested in the univariable analysis. A multivariable analysis was not performed.

Appendix Table 7. Sensitivities of initial CT and initial ultrasonography per site

Site	Sensitivity of initial CT, % (95% CI) [Numerator/Denominator]*	Sensitivity of initial ultrasonography, % (95% CI) [Numerator/Denominator]*
Overall (unadjusted)	96.4 (95.5-97.2) [1,906/1,977]	100 (95-100) [76/76]
Overall (adjusted) [†]	95.6 (93.5-97.8) [1,906/1,977]	NA
Site 1	99.1 (97.9-99.7) [550/555]	100 (72-100) [11/11]
Site 2	98.3 (95.8-99.5) [237/241]	100 (86-100) [24/24]
Site 3	96.0 (92.6-98.2) [218/227]	100 (48-100) [5/5]
Site 4	93.6 (89.3-96.5) [190/203]	100 (40-100) [4/4]
Site 5	95.5 (91.6-97.9) [191/200]	100 (74-100) [12/12]
Site 6	96 (91-98) [135/141]	100 (16-100) [2/2]
Site 7	88 (80-93) [100/114]	100 (59-100) [7/7]
Site 8	95 (89-98) [113/119]	100 (3-100) [1/1]
Site 9	97 (91-100) [73/75]	100 (16-100) [2/2]
Site 10	100 (94-100) [61/61]	100 (48-100) [5/5]
Site 11	93 (80-99) [38/41]	100 (29-100) [3/3]

Numerators and denominators do not include cases with unavailable CT (n = 102), ultrasonography (n = 63), or pathology (n = 1) reports. *Indeterminate results were counted as a positive diagnosis; [†]Adjusted for clustering by site. CI, confidence interval; CT, computed tomography; NA, unable to calculate.

Appendix Table 8. Subgroup analysis for the sensitivities of initial CT

Variable	Sensitivity, % (95% CI) [Numerator/Denominator]*	Univariable analysis, OR (95% CI)	Multivariable analysis, AOR (95% CI)
Age (yr)			
15-44	95.9 (94.7-96.9) [1,219/1,271]	0.61 (0.37-1.00)	0.56 (0.33-0.98)
≥ 45	97.3 (95.8-98.4) [687/706]	1 [Reference]	1 [Reference]
Sex			
Male	98.2 (97.2-98.9) [1,044/1,063]	1 [Reference]	1 [Reference]
Female	94.3 (92.6-95.7) [862/914]	0.36 (0.21-0.60)	0.31 (0.18-0.54)
Reproductive female			...
Female 15-44 yr	93.7 (91.3-95.5) [532/568]	0.41 (0.26-0.66)	
Others	97.5 (96.6-98.3) [1,374/1,409]	1 [Reference]	
Body mass index (kg/m ²) [†]			
Underweight (< 18.5)	94 (89-97) [129/137]	0.69 (0.33-1.40)	0.87 (0.40-1.90)
Normal (18.5-24.9)	96.1 (94.9-97.1) [1,265/1,316]	1 [Reference]	1 [Reference]
Overweight (25.0-29.9)	97.2 (95.1-98.5) [415/427]	1.26 (0.72-2.20)	0.95 (0.49-1.83)
Obesity (≥ 30.0)	100 (95-100) [74/74]	NA	NA
Missing	100 (85-100) [23/23]	NA	NA
Time of presentation in emergency department			
Working hours [‡]	95.8 (94.0-97.3) [600/626]	0.72 (0.46-1.13)	0.64 (0.39-1.06)
After hours	96.7 (95.6-97.6) [1,306/1,351]	1 [Reference]	1 [Reference]
Time to appendectomy (hr) ^{§,¶}			...
< 6	97.1 (95.8-98.2) [812/836]	1 [Reference]	
6-12	96.3 (94.6-97.6) [633/657]	0.89 (0.53-1.50)	
≥ 12	95.2 (92.9-97.0) [441/463]	0.75 (0.43-1.31)	
Mode of surgical approach			...
Laparoscopy	95.3 (94.1-96.4) [1,289/1,352]	1 [Reference]	
Open	98.7 (97.4-99.4) [591/599]	1.78 (0.89-3.58)	
Conversion	100 (87-100) [26/26]	NA	
Time to discharge (d) ^{,¶}			...
< 4	95.9 (94.6-97.1) [1,018/1,061]	0.80 (0.50-1.26)	
≥ 4	97.0 (95.6-98.0) [868/895]	1 [Reference]	
Site annual appendectomy volume**			
< 240	94.4 (92.8-95.8) [901/954]	0.36 (0.16-0.82)	0.31 (0.15-0.64)
≥ 240	98.2 (97.2-99.0) [1,005/1,023]	1 [Reference]	1 [Reference]

Cases with unavailable CT (n = 102) or pathology (n = 1) reports were not included in the analysis. Ellipsis indicates that the variable was not tested in the multivariable analysis. *Indeterminate results were counted as a positive diagnosis; [†]Weight in kilograms divided by the square of the height in meters; [‡]8:00 AM to 5:00 PM on working days; [§]Defined as the interval from the emergency department visit to the induction of anesthesia for appendectomy; [¶]Defined as the interval from the emergency department visit until hospital discharge; ^{||}Does not include 23 cases of interval appendectomy; **Number of patients included in the study. AOR, adjusted odds ratio; CI, confidence interval; CT, computed tomography; NA, not applicable or unable to calculate; OR, odds ratio.

9. References

1. Statistics Korea. 2010 Population and housing census: complete enumeration result. Available at http://www.census.go.kr/hcensus/ui/html/data/data_020_010_Detail.jsp?p_bitmId=60458&q_menu=4&q_sub=2&q_pageNo=1&q_div=ALL [accessed on May 23 2013].
2. National Health Insurance Service. 2011 Statistics on major surgeries in Korea. Available at http://www.bokjiro.go.kr/data/statusView.do?board_sid=297&data_sid=5999111 [accessed on 20 May 2013].
3. Health Insurance Review & Assessment Service of Korea. Hospital survey. Available at <http://www.hira.or.kr/main.do> [accessed on 21 May 2013].
4. Sim JY, Kim HJ, Yeon JW, Suh BS, Kim KH, Ha YR, Paik SY. Added value of ultrasound re-evaluation for patients with equivocal CT findings of acute appendicitis: a preliminary study. *Eur Radiol* 2013; 23: 1882-90.
5. Kim K, Kim YH, Kim SY, Kim S, Lee YJ, Kim KP, Lee HS, Ahn S, Kim T, Hwang SS, Song KJ, Kang SB, Kim DW, Park SH, Lee KH. Low-dose abdominal CT for evaluating suspected appendicitis. *N Engl J Med* 2012; 366: 1596-605.
6. Daly CP, Cohan RH, Francis IR, Caoili EM, Ellis JH, Nan B. Incidence of acute appendicitis in patients with equivocal CT findings. *Am J Roentgenol* 2005; 184: 1813-20.
7. Paulson EK, Kalady MF, Pappas TN. Clinical practice. Suspected appendicitis. *N Engl J Med* 2003; 348: 236-42.