Radiology

Screening of Illegal Intracorporeal Containers ("Body Packing"): Is Abdominal Radiography Sufficiently Accurate? A Comparative Study with Low-Dose CT[1]

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Purpose: To evaluate the diagnostic performance of abdominal radiography in the detection of illegal intracorporeal containers (hereafter, packets), with low-dose computed tomography (CT) as the reference standard.

Materials and Methods: This study was approved by the institutional ethical review board, with written informed consent. From July 2007 to July 2010, 330 people (296 men, 34 women; mean age, 32 years [range, 18–55 years]) suspected of having ingested drug packets underwent supine abdominal radiography and low-dose CT. The presence or absence of packets at abdominal radiography was reported, with low-dose CT as the reference standard. The density and number of packets (≤12 or >12) at low-dose CT were recorded and analyzed to determine whether those variables influence interpretation of results at abdominal radiography.

Results: Packets were detected at low-dose CT in 53 (16%) suspects. Sensitivity of abdominal radiography for depiction of packets was 0.77 (41 of 53), and specificity was 0.96 (267 of 277). The packets appeared isoattenuated to the bowel contents at low-dose CT in 16 (30%) of the 53 suspects with positive results. Nineteen (36%) of the 53 suspects with positive low-dose CT results had fewer than 12 packets. Packets that were isoattenuated at low-dose CT and a low number of packets (≤12) were both significantly associated with false-negative results at abdominal radiography (P = .004 and P = .016, respectively).

Conclusion: Abdominal radiography is mainly limited by low sensitivity when compared with low-dose CT in the screening of people suspected of carrying drug packets. Low-dose CT is an effective imaging alternative to abdominal radiography.

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The care of persons suspected of having swallowed drug containers is a complex procedure that usually integrates the results of specific investigations (1,2). Once a person has been suspected of carrying intracorporeal drug containers, he or she is usually referred to a medical center to undergo a radiologic examination. Usually, this examination consists of abdominal radiography, which is used to confirm or discredit the prior suspicion and, thus, to determine whether stool analysis is required (3–5). However, the value of abdominal radiography to screen for intracorporeal containers has not, to our knowledge, been prospectively evaluated in a large series of suspects with computed tomography (CT) as the reference standard. Indeed, although CT has been reported to be the most accurate imaging method with which to display intraabdominal containers (6–11), the radiation dose typically delivered with this technique is a major limitation in its systematic use to screen persons suspected of conveying these containers. This concern can now be overcome by the use of low-dose CT protocols, which deliver a radiation dose close to that of abdominal radiography. These low-dose CT protocols have been reported to be accurate in screening for well-defined medical conditions, such as renal colic (12) and appendicitis (13–15). They have also recently been reported as useful in demonstrating the presence of an intracorporeal drug packet (16,17).

The purpose of this study was to evaluate the diagnostic performance of abdominal radiography in the detection of illegal intracorporeal containers (hereafter, packets), with low-dose CT as the reference standard.

Materials and Methods

This research was approved by the research ethics committee of our institution (CER 06–023); written informed consent was obtained before any radiologic investigation was performed. A pregnancy test was systematically obtained before abdominal radiography was performed in each woman of childbearing age who agreed to undergo imaging. Persons who declined to participate in the study, those younger than 18 years of age, and pregnant women were excluded from the study. Those individuals stayed at the hospital to undergo a stool analysis under medical control.

During the study period (July 2007–July 2010), all consecutive adults suspected of having ingested drug packets within the Geneva State territory in Switzerland (n = 338) were systematically brought to our emergency department. A total of 332 consented to participate. Two women were pregnant and thus were excluded. The final study population consisted of 296 (90%) men (mean age, 33 years [range, 18–55 years]) and 34 (10%) women (mean age, 32 years [range, 18–55 years]).

Immediately after admission to our emergency radiology unit, suspects underwent supine abdominal radiography. The radiograph was immediately interpreted by the radiologist on call (a fellow or a senior resident). The prior training was 5–6 years of general radiology for the fellows and 3–5 years for the residents, including at least 6 months of conventional radiology and 2 years of body CT. Twenty-two fellows or senior residents read the results of abdominal radiography and low-dose CT during the study period. Before study initiation, all were accustomed to reading abdominal radiographs for the screening of drug packets; they were also familiar with interpreting findings at abdominal low-dose CT because this test is routinely used in our institution (12,14,18). The radiologist on call reported on a standardized electronic form whether an abdominal radiograph was considered positive or negative for the presence of packets. Findings were considered positive when at least one of the following findings was present (19): *(a)* one or multiple well-defined opacities in the stomach, small bowel, or colon, that were not suggestive of alimentary content; *(b)* the "double condom sign" (Fig 1), defined as a definite crescent of air surrounding an ovoid opacity (3); *(c)* a smooth and uniformly shaped oblong structure (sometimes called the "tic-tac sign" [19]); or *(d)* the parallelism sign, defined as "rigid packages aligning parallel to each other in the bowel lumen" (19). The radiologist was also asked to report the degree of confidence in the interpretation of the abdominal radiograph for the presence

Advances in Knowledge

- Abdominal radiography has limited sensitivity (0.77) in the screening of illegal intracorporeal containers when compared with low-dose CT.
- Illegal intracorporeal packets are difficult to detect with abdominal radiography when they are present in small numbers (≤12).
- The sensitivity of abdominal radiography in the detection of illegal intracorporeal containers is lower (0.50) when the containers appear isoattenuated to the bowel content at low-dose CT than when they appear to have higher attenuation (0.89).

Implication for Patient Care

- Performing low-dose CT instead of abdominal radiography will improve the detection of illegal intracorporeal packets, without increasing the radiation dose.

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Abbreviation:
BMI = body mass index

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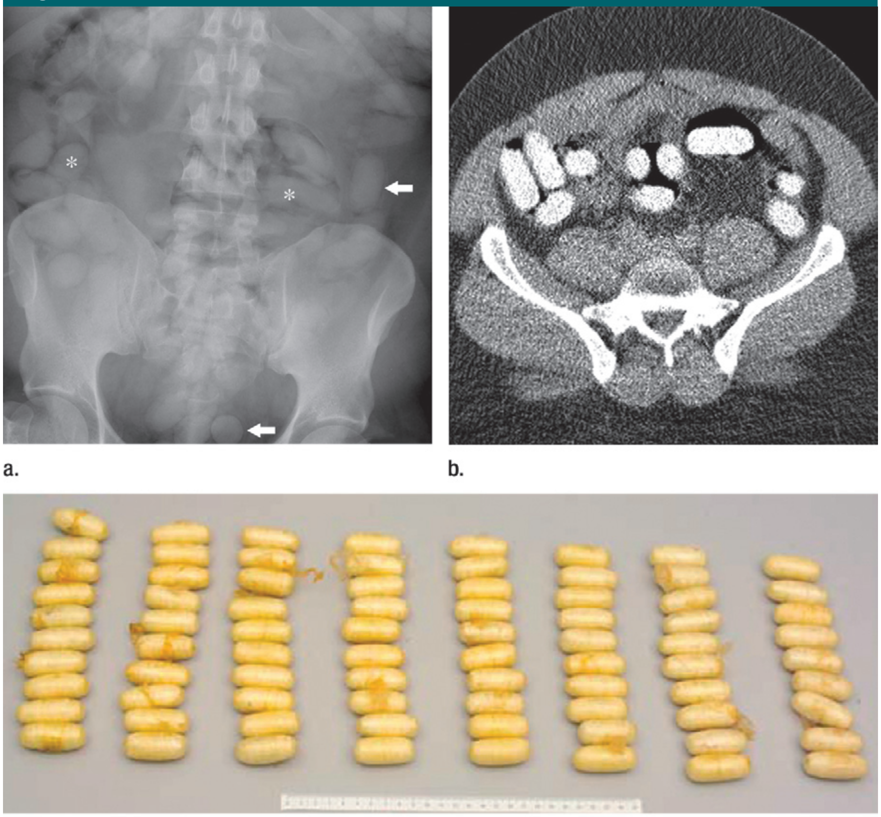
Conflicts of interest are listed at the end of this article.

Figure 1



a. b. c.

Figure 1: **(a)** True-positive abdominal radiograph at admission in a 30-year-old man suspected of conveying drug packets shows multiple well-defined smooth and uniformly shaped oblong opacities (*) spread throughout the abdomen, with peripheral crescent of air or "double condom sign" (arrows) (3), consistent with drug packets. The radiologist on call rated this radiograph as positive, with very high confidence (4 of 4) in his diagnosis. **(b)** Axial low-dose CT image shows a large quantity (>12) of intraintestinal packets, hyperattenuated to the surrounding bowel content. **(c)** Eighty containers stuffed with cocaine were found at stool analysis.

or absence of packets on a scale of 1–4 (1 = minimal confidence in the diagnosis, 2 = moderate confidence, 3 = good confidence, 4 = excellent confidence). The suspect's body mass index (BMI) was also recorded.

Once the abdominal radiographic findings were interpreted, the suspect underwent abdominal low-dose CT. The CT scan was also immediately interpreted as positive or negative for the presence of packets by the same radiologist. The interpretation of low-dose CT findings was also reported on an electronic form. The radiologist had to indicate whether the number of foreign bodies depicted at low-dose CT was 12 or fewer (Fig 2) or more than 12. The visual aspect of the packets at low-dose CT was reported as isoattenuated (Fig 3) or hyperattenuated with regard to the intestinal content.

A brief report that indicated the presence or absence of packets at both abdominal radiography and low-dose CT was given to the police or border guard authorities.

Reference Standards

Low-dose CT was considered the reference standard. When findings at low-dose CT were negative, no further examination was performed, and the suspect left the hospital. When low-dose CT findings were positive, the suspect was hospitalized in a dedicated ward of our institution and kept under surveillance for stool analysis. All collected packets were handed over to a dedicated laboratory for chemical characterization of the content.

Technical Imaging Parameters

Abdominal radiography was performed with the patient in the supine position by using an X-Ray Philips Optimus 65 unit with automatic exposure control (Philips Medical Systems, Best, the Netherlands).

Low-dose CT was performed with a 16-row Philips MX 8000 (Philips Medical Systems) unit and stretched from the lung bases to the pelvis. The examination was performed without administration of oral or rectal contrast material and with the following parameters: collimation, 16×1.5 mm; pitch, 1.25; gantry rotation period, 0.5 second; tube potential, 120 kV; tube charge per gantry rotation, 30 mAs (75 mA $\times$ 0.5 sec/1.25 = 30 mAs); and reconstruction section thickness, 3.0 mm.

Calculation of Effective Dose

Effective doses were estimated before protocol initiation. These included the following:

Abdominal radiography.—For a field of 35×43 cm, the entrance doses delivered by abdominal radiography ranged from 6.0 mGy (66 kV and 50 mA) to 12 mGy (73 kV and 120 mA), with a mean dose of 9 mGy $\pm$ 3.0 (standard deviation). Effective dose was computed by using ODS 60 software (Rados Technology, Turku, Finland) (20) and was 2.0 mSv $\pm$ 0.7 in women and 1.3 mSv $\pm$ 0.4 in men.

Low-dose CT.—The dose delivered by low-dose CT was estimated by using the ImPACT CT patient dosimetry calculator (21), with the default normalized weighted CT dose index of 7.0 mGy/100 mAs proposed at 120 kV (value compatible with our measurements within 10%). The following results were provided by the program: For women, dose-length product was 84 mGy · cm $\pm$ 10.5 and effective dose was 1.7 mSv $\pm$ 0.2; for men, dose-length product was 84 mGy · cm $\pm$ 10.5 and effective dose was 1.2 mSv $\pm$ 0.1.

Statistical Analysis

Abdominal radiographic findings were compared with results of low-dose CT (used as reference standard) to estimate sensitivity, specificity, and positive and negative predictive values for depiction of foreign bodies. The 95% confidence intervals of these statistics were estimated with the Clopper-Pearson method.

The radiologist's confidence in the analysis of abdominal radiographic findings was considered as an ordinal variable consisting of an eight-level scale ranging from negative findings with a confidence level of 4 (level 1) to positive findings with a confidence level of 4 (level 8). A receiver operating characteristic curve was obtained. The optimal cutoff for the radiologist's level of confidence was determined by maximizing the Youden index (sensitivity + specificity − 1) (22). Likelihood ratios were used to assess how informative the levels of confidence given by the radiologists were.

For considering only the cases that were positive at low-dose CT, a logistic regression model was obtained to test the influence of the conveyers' BMI (<25 kg/m^2 or ≥25 kg/m^2), as well as the influence of the attenuation and quantity of the packets when they were detected at abdominal radiography. Furthermore, sensitivities were computed on the strata defined by the attenuation (isoattenuated vs hyperattenuated) and quantity (≤12 vs >12) of the packets.

The significance level was fixed to 5% (two-tailed *P* value). Differences between two groups were tested with a *t* test for continuous variables and with the Fisher exact test for proportions. All analyses were performed by using R for Windows, version 2.13.0 (R Development Core Team, Vienna, Austria).

Figure 2

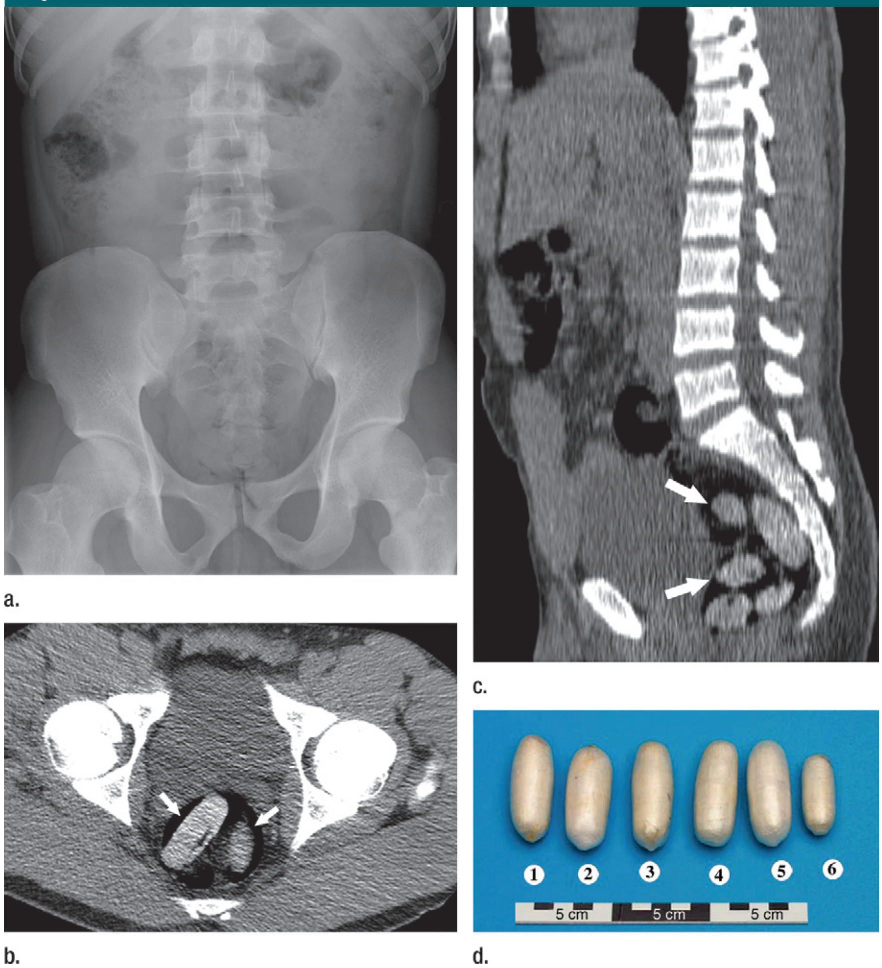


Figure 2: **(a)** False-negative abdominal radiograph at admission in a 26-year-old man suspected of conveying drug packets. This radiograph was initially deemed negative by the radiologist on call, with a low degree of confidence (1 of 4) in his diagnosis. **(b)** Axial and **(c)** sagittal multiplanar reformatted low-dose CT images show a small quantity (≤12) of packets within the rectum, hyperattenuated to the surrounding bowel content (arrows). **(d)** Six containers stuffed with cocaine were found at stool analysis.

Results

Population and Packet Characteristics

BMI was reported as less than 18.5 kg/m^2 (underweight) in 22 (7%) suspects, 18.5–25 kg/m^2 (normal) in 258 (78%) suspects, 25–30 kg/m^2 (overweight) in 44 (13%) suspects, and greater than 30 kg/m^2 (obese) in six (2%) susbects. Packets were detected at low-dose CT and found at stool analysis in 53 (16%) of the 330 suspects.

In 50 (94%) of the 53 true-positive cases, packet content consisted of cocaine hydrochlorate powder, as well as cutting agents, such as phenacetin, and weighed 7–25 g each (mean, 10.6 g). In three suspects, packets contained rolls of banknotes wrapped in cellophane bags. Packets were located in the bowel or rectum (*n* = 51) or vagina (*n* = 2 [eight packets of drugs in one suspect and one packet of banknotes in the other]). Twelve (23%) of the 53 drug conveyers carried one to six packets; seven (13%), seven to 12 packets; and 34 (64%), more than 12 packets.

Abdominal Radiography versus Low-Dose CT

The presence of packets was suspected by the radiologists at abdominal radiography in 51 (15%) of the 330 suspects. When compared with low-dose CT, 41 abdominal radiographs showed true-positive findings, 10 had false-positive findings, 267 had true-negative findings, and 12 had false-negative findings (Table 1).

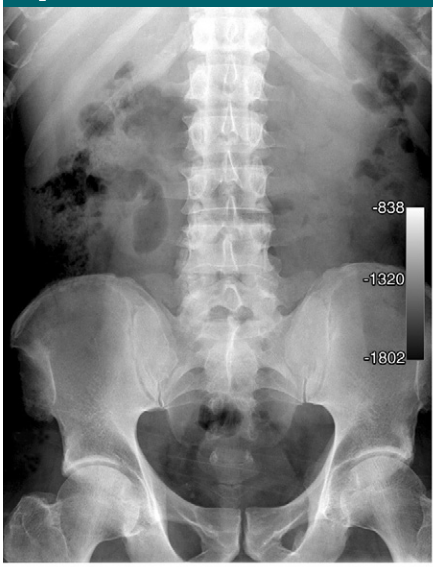
Table 1

Evaluation of Abdominal Radiography in Detection of Body Packets, with Low-Dose CT as Reference Standard

Test Characteristic	Estimated Value	95% Confidence Interval
Sensitivity	0.77 (41/53)	0.64, 0.88
Specificity	0.96 (267/277)	0.93, 0.98
Positive predictive value	0.80 (41/51)	0.67, 0.90
Negative predictive value	0.96 (267/279)	0.93, 0.98

Note.—Data in parentheses are raw data.

Figure 3



a.

b.

Figure 3: **(a)** False-negative abdominal radiograph at admission in a 54-year-old man suspected of conveying drug packets. This radiograph was initially deemed negative by the radiologist on call, with a low degree of confidence (1 of 4) in his diagnosis. **(b)** Axial low-dose CT scan shows a large quantity (>12) of packets within the stomach (arrowheads) and small bowel (arrow), isoattenuated to the surrounding gastric and bowel content. Thirty-six containers stuffed with cocaine were found at stool analysis.

Confidence of the Radiologist in Interpreting Abdominal Radiographs

The degree of confidence in the interpretation was equal to 1 in 17 (5%) of the 330 suspects, equal to 2 in 86 (26%) suspects, equal to 3 in 164 (50%) suspects, and equal to 4 in 63 (19%) suspects. The receiver operating characteristic curve associated with confidence in the analysis of abdominal radiographic findings considered as an ordinal eight-level variable showed good discrimination (Fig 4) because the area under the curve was 0.95. The optimal sensitivity and specificity (0.85 and 0.94, respectively) are obtained at the cutoff point of 4, when a negative result with a level of confidence of 1 is considered a positive result. This cut point leads to a positive predictive value of 74% (45 of 61) and a negative predictive value of 97% (261 of 269).

There was a strong likelihood ratio (>10 or <1/10) for positive or negative results at abdominal radiography when the confidence was high (level 3 or 4) (Table 2).

Influence of Conveyers' BMI and of Attenuation and Quantity of Packets at Interpretation of Abdominal Radiographs

Among the 53 persons who carried packets, 43 had a BMI less than 25 kg/m^2, and 10 had a BMI greater than 25 kg/m^2 (including one with a BMI >30 kg/m^2). The content of the packets was isoattenuated compared with the bowel content at low-dose CT in 16 (30%) of the 53 positive cases and as hyperattenuated in 37 (70%) cases. Nineteen conveyers carried 12 or fewer packets and 34 conveyers carried more than 12 packets. Results of univariate logistic regression analysis (Table 3) showed a nonsignificant association between a BMI greater than 25 kg/m^2 and a correct positive identification, but the attenuation of the packets and their quantity were significantly associated with true-positive status. The multivariate model enabled us to confirm these findings: Packets were more difficult to detect when they were isoattenuated or when there were fewer than 12.

The highest sensitivity (0.92 [24 of 26]) of abdominal radiography was achieved in the presence of multiple (>12) packets of high attenuation (Table 4). The lowest sensitivity (0.25 [two of eight]) was found in the presence of a small number of packets (≤12) of low attenuation.

Discussion

This study aimed to assess the value of abdominal radiography in the screening of body packers in comparison with that of low-dose CT. Although some reports have already stressed the limitations of abdominal radiography in this setting (2,6,7,23,24), its diagnostic performance in the identification of illegal packets remained uncertain because of the absence of a systematic reference standard in the prior reports. Indeed, no prior series systematically included a CT examination or a stool analysis in every suspect after the negative result of abdominal radiography was reported. The lack of a straightforward reference standard explains the wide range of sensitivities (from 0.40 to 1.00) that has been reported in the detection of intracorporeal containers with abdominal radiography (3,7,23,25). In our prospective study, abdominal radiography achieved an overall sensitivity of 0.77 (41 of 53) and an overall specificity of 0.96 (267 of 277) in the depiction of packets when compared with low-dose CT. Our results show that this technique is mainly limited by a high percentage (23% [12 of 53]) of false-negative cases. Hence, the diagnostic value of abdominal radiography in the screening of drug conveyers is probably overestimated and raises questions about its exact role and its limitations in this application. In addition, use of abdominal radiography as the sole screening test would have resulted in 4% (10 of 277) of innocent suspects being falsely considered guilty.

Our data show that the value of abdominal radiography is closely related to the confidence of the radiologist in his or her interpretation. High levels of confidence (3 or 4) were associated with high likelihood ratios, whereas low levels of confidence (1 or 2) were not. This observation suggests that abdominal radiography cannot be relied on to detect packets when the radiologist is not confident in his or her interpretation; in the current series, this corresponds to 31% (104 of 330) of our study group. In such situations, abdominal radiography should ideally be followed by low-dose CT. However, a CT unit is not always available after abdominal radiography has been performed, especially when the screening is not performed in a medical institution but rather, for instance, in a remote airport. Moreover, the additional cost of unenhanced CT often precludes systematic use of the test in this setting. When the screening of body packers was based on abdominal radiography alone, our results showed that the optimal ratio for sensitivity (0.85) and specificity (0.94) was obtained by considering a negative abdominal radiograph with a lower level of confidence (1 of 4) as a positive result (cutoff point). Doing so will still lead to a 15% rate of false-negative abdominal radiographic findings and a 6% rate of false-positive findings. Our results did not show any relationship between the suspects' BMI and abdominal radiographic findings. However, the group of overweight body packers (BMI ≥ 25 kg/m^2) included only one obese person (BMI > 30 kg/m^2); therefore, it is impossible to draw any conclusion with regard to this specific subgroup.

The last objective of the study was to retrospectively determine whether the apparent attenuation of the packets at low-dose CT or their quantity might have influenced their detectability at abdominal radiography. Our results showed that the density and number of packets at low-dose CT were significantly correlated to the rate of false-negative readings at both uni- and

Table 2

Results of Interpretation of Abdominal Radiography according to Radiologist's Confidence in Interpretation with Low-Dose CT Used as Reference Standard

Variable	Positive Low-Dose CT Result	Negative Low-Dose CT Result	Likelihood Ratio*
Negative radiograph, high confidence[†]	2 (3.8)	187 (67.5)	0.06
Negative radiograph, low confidence[‡]	10 (18.9)	80 (28.9)	0.65
Positive radiograph, low confidence	5 (9.4)	8 (2.9)	3.27
Positive radiograph, high confidence	36 (67.9)	2 (0.7)	94.08
Total	53 (100)	277 (100)	…

Note.—Unless otherwise noted, values are expressed as numbers of cases, with percentages in parentheses.

* High confidence = score of 3 or 4 on a four-level scale.

[†] Low confidence = score of 1 or 2 on a four-level scale.

[‡] Likelihood ratio is considered strong when >10 or <1/10.

Figure 4

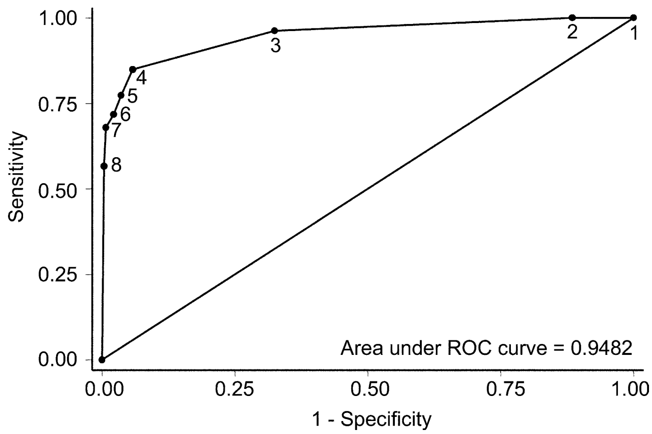


Figure 4: Receiver operating characteristic curve shows the sensitivity and specificity of interpretation of abdominal radiographs for the presence of intracorporeal packets, with regard to the radiologist's level of confidence in the interpretation. Points *1–8* correspond to sensitivity and specificity for depiction of packets if the abdominal radiograph was considered positive at these threshold levels. *1,* Abdominal radiograph deemed negative by the radiologist, with a high level of confidence (4 of 4). *2,* Abdominal radiograph deemed negative (level of confidence, 3). *3,* Abdominal radiograph deemed negative (level of confidence, 2). *4,* Abdominal radiograph deemed negative (level of confidence, 1). *5,* Abdominal radiograph deemed positive (level of confidence, 1). *6,* Abdominal radiograph deemed positive (level of confidence, 2). *7,* Abdominal radiograph deemed positive (level of confidence, 3). *8,* Abdominal radiograph deemed positive (level of confidence, 4). Optimal sensitivity and specificity (0.85 and 0.94, respectively) are obtained at the cutoff point of 4, when a negative result with a level of confidence of 1 is considered a positive result.

Table 3

Association between Suspect's BMI and Quantity and Attenuation of Packets and Their Detection at Abdominal Radiography Compared with Those at Low-Dose CT

	Univariate Analysis		Multivariate Analysis	
Variable	Odds Ratio	*P* Value	Odds Ratio	*P* Value
BMI	1	…	…	…
<25 kg/m²*	3.1 (0.4, 27.3)	.31	…	…
≥25 kg/m²	…	…	…	…
Attenuation*	1	…	1	…
Isoattenuation*	8.3 (2.0, 34.4)	.004	7.5 (1.6, 33.7)	.009
Hyperattenuation	…	…	…	…
Quantity	1	…	1	…
≤12*	…	…	…	…
>12	5.5 (1.4, 21.8)	.016	4.8 (1.1, 21.9)	.042

Note.—Data in parentheses are 95% confidence intervals.

* Reference level for comparison.

Table 4

Sensitivity of Abdominal Radiography in Depiction of Intracorporeal Packets with Regard to Quantity and Attenuation at Low-Dose CT

Variable	No. of Cases	Sensitivity
Attenuation		
Isoattenuation	8/16	0.50 (0.25, 0.75)
Hyperattenuation	33/37	0.89 (0.75, 0.97)
Quantity		
≤12 packets	11/19	0.58 (0.33, 0.80)
>12 packets	30/34	0.89 (0.73, 0.97)
Both variables		
Isoattenuation with ≤12 packets	2/8	0.25 (0.03, 0.65)
Isoattenuation with >12 packets	6/8	0.75 (0.35, 0.97)
Hyperattenuation with ≤12 packets	9/11	0.82 (0.48, 0.98)
Hyperattenuation with >12 packets	24/26	0.92 (0.75, 0.99)

Note.—Data in parentheses are 95% confidence intervals.

multivariate analysis. The association between the radiologic attenuation of various drugs and their possible presentations (eg, powder, stones, tablets, pills) has already been reported in extracorporeal analyses (5).

The fact that the sensitivity of abdominal radiography was only 0.50 (eight of 16) in suspects carrying iso-opaque packets compared with 0.89 (33 of 37) in those carrying opaque containers suggests that the increased radiologic attenuation constitutes a major sign for their detection at abdominal radiography. Furthermore, the sensitivity dropped to 0.25 (two of eight) when packets were both isoattenuated and small in quantity (≤12). With the improvement in packet manufacturing, it would not be surprising if a majority of intracorporeal containers became undetectable at abdominal radiography in a short time. This supposition is bolstered by recent reports of incidental seizure of liquid or mushy forms of intraabdominally concealed cocaine packets that remained undetectable at abdominal radiography, even after retrospective analysis (R. Mourachko, oral communication [Council of Europe, Annual Airport Group Meeting, Strasbourg, France], 2011).

Our study had several limitations. Packets consisted exclusively of large fingerlike containers that weighed 7–25 g each. Thus, our data certainly cannot be transposed to a population of smugglers using smaller drug packets, sometimes called "body stuffers" or "mini-packers" (10). In the latter situation, it is possible that interpretation of abdominal radiographs would have led to a higher rate of false-negative interpretations.

Similarly, in the current study, intracorporeal packets contained only cocaine hydrochlorate powder (along with cutting agents) and banknotes (in three suspects), a finding linked to the local trends in drug trafficking. Whether our results can be extrapolated to other packet content (such as heroin or liquid cocaine) remains an open question.

Another limitation of our study was that the experience of the radiology residents or fellows in interpreting abdominal radiographs was not evaluated, and interobserver variability was not assessed. It is possible that the performance of abdominal radiography could have been improved if the findings had been systematically read by attending radiologists.

Finally, the methods of the current series were based on the postulate that low-dose CT is a reference standard in the detection of intracorporeal containers. However, to our knowledge, no studies have been performed to evaluate a negative low-dose CT scan (or even a standard CT scan) with a systematic stool analysis. Because the sensitivity of low-dose CT in the detection of intraabdominal packets is unknown, we cannot completely rule out the possibility that some intracorporeal containers may have been missed at both abdominal radiography and low-dose CT. Nevertheless, our study results showed the high specificity of low-dose CT in this setting; indeed, all positive low-dose CT scans in our study population were confirmed at stool analysis, without any report of false-positive cases.

In conclusion, the current study shows that the detection of illegal intraabdominal containers with abdominal radiography is related to their radiologic attenuation and to their quantity. The interpretation of abdominal radiographs should consider the radiologist's level of confidence in the interpretation to optimize both sensitivity and specificity. The use of low-dose CT may constitute a reasonable alternative to abdominal radiography to improve the detection of illegal intraabdominal packets.

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