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Case report

Pearl-white gallstones: A report of a case and a chemical analysis by FTIR and XRD

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ABSTRACT

Introduction: Gallstones' color is usually yellow, brown, black or more commonly a mixture of two or more of these colors in different proportions, depending on their composition, with yellow being the most commonly encountered color. Pearl-white gallstones are a very rare entity that has not been studied and reported sufficiently.

Case presentation: Our patient is a 44-year-old lady who was suffering from recurrent attacks of epigastric and right hypochondrial abdominal pain that was aggravated by consumption of fatty meals. Ultrasound Imaging revealed multiple gallbladder stones. After an elective cholecystectomy unusual pearl-white gallstones were found inside a distended gallbladder filled with transparent thick fluid.

Chemical analysis: To evaluate the chemical composition of these stones Fourier-transform infrared (FTIR) spectroscopy and X-Ray Diffraction (XRD) tests were performed and revealed that these stones are composed of cholesterol (99.6%) and calcium carbonate (0.4%).

Discussion: Gallstones are bile depositions of a solid consistency formed inside the gallbladder. Cholesterol, bilirubin, and other substances are involved in the composition of different kinds of gallstones. The presence of gallstones alone inside the gallbladder is usually presented as colicky abdominal pain. Cholecystectomy is a simple surgical removal of the gallbladder from it bed and is the definitive treatment of gallstone disease.

Conclusion: Pearl-white gallstones are rarely encountered and lack information about their pathogenesis, thus prompting further evaluation and studying.

1. Introduction

Gallstones are solid stone-like objects formed as deposits of bile in the gallbladder or bile ducts that vary in size, shape, and color [1]. They are mainly composed of cholesterol, bilirubin, or substances like calcium salt precipitates [2]. There are a number of classifications for gallstones based on their components, the most common of which are pure cholesterol stones which are mainly composed of cholesterol, pigment stones which are mainly composed of bilirubin, and mixed composition stones which are composed of mixtures of bilirubin, cholesterol and calcium salts in different proportions [3–5]. The most common color of gallstones is yellow. However, based on the proportion of substances forming the gallstones, their colors may vary and range between yellow, brown, and black [6,7]. Interestingly, we report the first case of pearl white gallstones in Jordan and the Arab population that were discovered after a laparoscopic cholecystectomy in a 44-year-old female. This case report has been reported in line with the SCARE Criteria [8].

2. Case presentation

A 44-year-old female, with a free past medical and surgical history, presented to the Outpatient Department (OPD) with recurrent episodes of epigastric and right hypochondrial pain radiating to the right shoulder for two weeks duration. The pain was associated with nausea and vomiting and was exacerbated by eating fatty food. An ultrasound was done and revealed multiple hyperechoic gallstones with posterior acoustic shadowing (Fig. 1). Ten days after the diagnosis, the patient underwent an elective laparoscopic cholecystectomy. The surgery was

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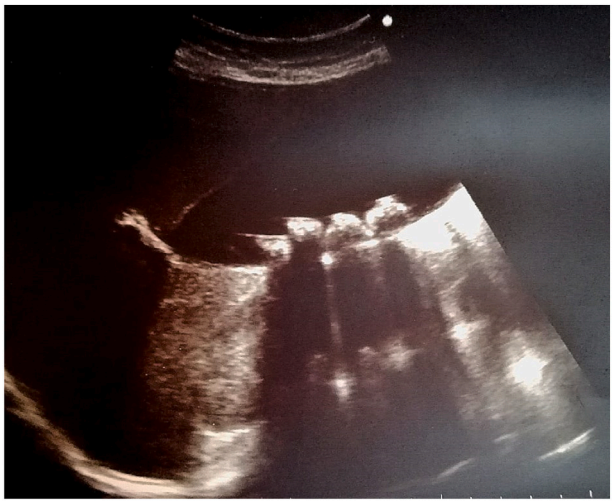

Fig. 1. Ultrasonographic imaging showing multiple hyperechoic gallstones with posterior acoustic shadowing.

performed under general anesthesia. An infra-umbilical incision (open method) was used to introduce the first trocar (optic port) and then insufflations followed to create pneumoperitoneum. Epigastric trocar and 2 other 5-mm subcostal trocars at midclavicular and anterior axillary lines were inserted. A distended gallbladder was noticed. Aspiration revealed a large amount of transparent sticky fluid (mucocele). Sharp and blunt dissection in Calot triangle was done to reveal the cystic duct and artery, which were clipped proximally and distally and cut in-between. The gallbladder was dissected from its bed and retrieved outside. Upon opening the gallbladder, pearl-white gallstones were noticed (Fig. 2). The obtained gallstones were not saved or placed in any kind of reagents.

The whole procedure was thoroughly explained to the patient. The post-operative course went smoothly without any complications. The patient was seen in the clinic two weeks later and was doing well.

3. Chemical analysis

3.1. Materials and methods

For this study, we used Fourier-transform infrared (FTIR) spectroscope and X-Ray Diffraction (XRD) analysis to identify the main composition material of the gallstones. The gallstones were first cleaned by distilled water to remove any residual or foreign materials. Then they were crushed into fine powder.

3.1.1. Fourier-transform infrared (FTIR) spectroscopy

Fourier-transform infrared (FTIR) technique is used to obtain the infrared spectrum of transmission or absorption of a sample to identify the organic compounds in the sample by identifying the different functional groups. The technique has been widely used in medicine since the 1960s [9,10].

In our study, the samples were homogenized with KBr and prepared in a pellet shape. FTIR analysis were performed using FTIR spectrometer of Bruker Tensor 27 FT in the spectral region 400 to 4000 cm^{-1} with a spatial resolution of 4 cm^{-1}. About 5 mg of the fine powder was mixed with KBr and pressed into disk shape for measurements. The FTIR spectra were compared with IR spectra database and with other data reported in other sources.

3.1.2. X-Ray diffraction (XRD)

X-ray powder diffraction (XRD) technique was used to identify the crystalline phase of the stones. Powder material of the stones were compressed in the holder and measured using continuous scanning mode on PANalytical diffractometer system (X'Pert PRO) using Cu tube and using diffraction intensities from 2Åã to 60Åã.

3.2. Results

3.2.1. Fourier-transform infrared (FTIR) spectroscopy

The analysis of the spectrum is based on comparison with standard Control spectra from the Literature spectra of pure cholesterol, bilirubin, and calcium carbonate standard [9,11–13].

The FTIR spectrum in (Fig. 3) shows that the composition of the stones is dominated by cholesterol crystal. The presence of Cholesterol is characterized by broad and intense band attributed to O—H stretching around 3420 cm^{-1} and a strong peak around 2892 due to CH2 symmetric stretching vibration. Other peaks attributed to cholesterol molecule is the double band (C═C) in the second ring of cholesterol molecule is detected at 1664 cm^{-1}. Finally, the cholesterol molecule is identified through the peak at 1465 cm^{-1} which is related to anasymmetric stretching vibration of CH2 and CH3 groups and the peak at 1381 cm^{-1} which is attributed to the CH2 and CH3 bending vibration of cholesterol molecule.

The Calcium bilirubinate was hard to be identified in the stones. Usually, it is characterized by doublet absorption peaks at 3398 cm^{-1}

Fig. 2. Pearl-White gallstones.

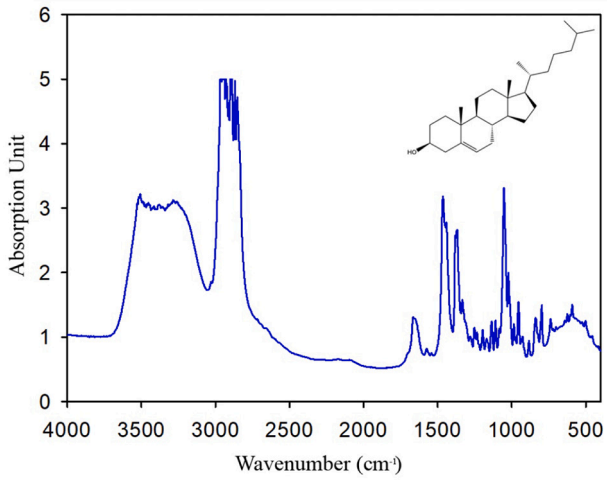

Fig. 3. Fourier-transform infrared (FT-IR) spectrum of the gallstone with the main fingerprint in the region 4000–400 cm^{-1}. Inset is the chemical structure of cholesterol.

(sharp peak) and 3264 cm^{-1}(broad peak), both peaks are attributed to N—H stretching vibration of the pyrrole groups. Another characteristic band for Calcium bilirubinate is at 1254 cm^{-1} which is also attributed to (C—O) stretching or C—N stretching. A triplet peaks at 1663, 1624, and 1566 cm^{-1} that identifies Calcium bilirubinate also is missing in the FTIR spectrum.

3.2.2. X-Ray diffraction (XRD)

X-Ray Diffraction (XRD) data was analysed using Match software with COD Inorganic 2011.06.14 database to identify the main crystalline phases in the stones. (Fig. 4) shows the XRD patterns for the stones. The intense reflection peaks indicated to the existence of crystalised cholesterol in its two phases: anhydrous and monohydrate. Dominant peak of anhydrous cholesterol at 2θ around 5.1 and 7.66, and 14.76. The monohydrate is indicated by 2θ at 15.62, 16.18, 17.48, 18.16, 19.10, 20.58 and 23.12°. Calcium carbonates are detected by the main peak at 2θ = 43.8.

In conclusion, the gallstones were composed of Cholesterol molecules based on the results of FTIR and XRD analysis. The XRD showed that the cholesterol is dominant with 99.6% and only 0.4% of calcium carbonates.

4. Discussion

Gallstones were described firstly by Antonio Benivenius in 1507 and are defined as solid bile deposits in the form of abnormal masses in the gallbladder or biliary tract that vary in size, shape, color, and composition depending on the solubility and saturation of composing substance [14,15]. Gallstones are composed mainly of cholesterol, bilirubin, phospholipids, mucopolysaccharides, glycoproteins, and calcium phosphate, bilirubinate, carbonate, and palmitate [16–19].

Gallstones are generally found in 10–15% of adult population [20]. In the United States, gallstone disease affects 14.2 million females (16.6%) and 6.3 million males (7.9%) ranging between 20 and 70 years of age, with an incidence rate of 0.63/100 persons each year and a mortality rate of 0.6% [20–22].

A variety of mechanisms stand behind the pathophysiology of gallstones such as bile super-saturation, alteration of bile composition, gallbladder mucus overproduction, biliary stasis, and decreased gallbladder motility [23,24].

Several factors are responsible for the increased incidence of gallstone disease. Elevated estrogen levels related to pregnancy, combined oral contraceptives use, and hormonal therapy have been reported to increase the levels of cholesterol in bile and decrease the motility of the gallbladder [25,26]. Increased age over the age of 40 [27,28], dietary choices represented by increased fat intake, refined sugars, and low fiber diets have demonstratedan association with the prevalence of gallstone disease [29,30]. Moreover, rapid weight loss, physical inactivity, obesity, insulin resistance, and type II Diabetes Miletus (DM) play major roles in assessing the formation of gallstones [31–34].

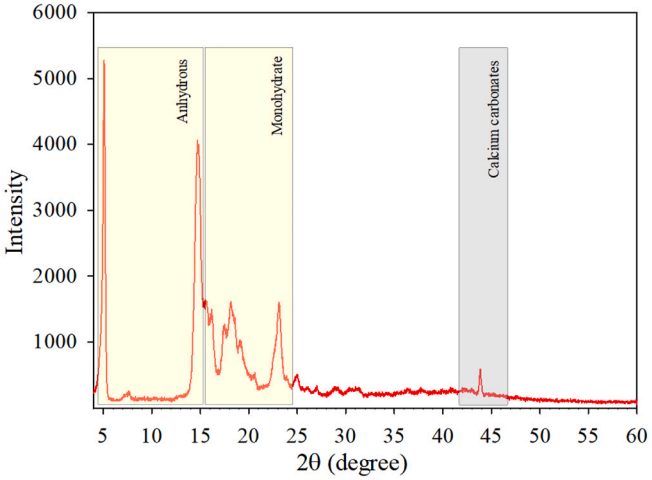

Fig. 4. XRD analysis for the gallstones.

Gallstone disease may present as an abdominal, shoulder, or back-pain, fever, nausea, and vomiting [35–38]. Jaundice and dark urine may occur because of Common Bile Duct (CBD) obstruction leading to the entry of bilirubin into the bloodstream [39,40]. Moreover, scanty bile secretions in small bowels caused by CBD obstruction may lead to pale stool [41].

Such disease may complicate into acute cholecystitis [42], acute cholangitis [43], pancreatitis as a result of pancreatic duct obstruction [44], cholecystoenteric fistula between an inflamed gallbladder and adjoining part of the gastrointestinal tract [45], Bouveret's syndrome which is known as bowel obstruction by large gallstones in the duodenal bulb [46], gallbladder empyema (suppurative cholecystitis) [47], and gallbladder cancer [48].

Abdominal ultrasound is considered the most common used method of diagnosis of the presence of gallstones as it has the sensitivity of 90–95% [49,50]. Many other methods are used but are less frequent than abdominal ultrasound such as Computed Tomography (CT), Endoscopic Retrograde Cholangiopancreatography (ERCP), hepatobiliary iminodiacetic acid (HIDA) scan, or Magnetic Resonance Cholangiopancreatography (MRCP). Also, sometimes blood tests can be useful in the diagnosis of such cases [51–54].

Symptomatic gallstones are treated by the surgical removal of the gallbladder either laparoscopically, or by an open cholecystectomy [55,56].

Gallstones are divided into many types in the medical literature but mainly divided into three categories based on their cholesterol content; cholesterol gallstones, which represent 75% of all gallstones with a yellow color and are mostly composed of cholesterol, pigmented gallstones representing 20% of all gallstones and are usually black or brown in color, and mixed composition stones representing 5% of gallstone types [59–62].

A publication entitled “A comparative study of gallstones from children and adults using FTIR spectroscopy and fluorescence microscopy” by Kleiner et al., studied the chemical characteristics of gallstones obtained from 21 children and 67 adults. The stones that went under FTIR spectroscopy varied in color, shape, and size, but the emphasis was on the composition of black, brown and green stones. In the study green stones were described as being similar to white stones in having a very high content of cholesterol [63].

Stoner et al. published a case report named “Pearl-White Gallstones Causing Choledocholithiasis” in 2018; the authors presented a rare case of white gallstones retrieved from the common bile duct during ERCP that involved sphincterotomy and balloon extraction. The reasons behind the bizarre white color of the stones and their chemical components were not discovered [64]. Our chemical analysis showed that pearl-white gallstones are composed mainly of cholesterol (99.6%) mixed with a small amount of calcium carbonate (0.4%).

5. Conclusion

Pearl-white gallstones are very rarely encountered. Our study found that these stones are composed mainly of cholesterol just like other types of gallstones. The cause and pathogenesis of such stones is not reported yet in literature. So, further attention should be focused on such entities.

Source of funding

None.

Ethical approval

Ethical approval for case reports and case series are waived according to the ongoing regulations of Yarmouk university.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in Chief of this journal on request.

Author contributions

R.D and A.A: Case report design and patient medical and surgical care.

R.D and S.A and M.A and F·H: Wrote the initial draft of the case report.

S.A.K and S.A and M.A: FTIR and XRD analysis of the stones.

R.D and A.A: revised the manuscript.

All authors read and approved the content of the submitted case report.

Research registration

This case report is not eligible for obtaining a research registry since it only contains a report of a known entity with no new surgical or medical interventions.

Guarantor

Mohammad Araydah.

Availability of data and materials

All data related to the outcome are included in the manuscript. Mentioned video can be found in the supplementary materials.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Declaration of competing interest

All authors declare that they have no conflict of interest.

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References

[1] N.A. Channa, F.D. Khand, T.U. Khand, M.H. Leghari, Memon ANJPJoms, in: Analysis of Human Gallstones by Fourier Transform Infrared (FTIR) 23(4), 2007, p. 546.
[2] X. Li, X. Guo, H. Ji, G. Yu, P. Gao, Gallstones in patients with chronic liver diseases, Biomed. Res. Int. 2017 (2017) 9749802.
[3] P. Portincasa, A. Moschetta, G. Palasciano, Cholesterol gallstone disease, Lancet (London, England) 368 (9531) (2006) 230–239.
[4] I.A. Bouchier, The formation of gallstones, Keio J. Med. 41 (1) (1992) 1–5.
[5] Y. Zhang, L. Zhang, H. Yang, H. Zhang, Y. Zhu, 1291 cases of cholelithiasis treated with electric shock on otoacupoints, J. Tradit. Chin. Med. 11 (2) (1991) 101–109.
[6] C.S. Shim, The color of gallstones: yellow, brown or black. present features of korean gallstone disease, Gastrointest. Endosc. 52 (1) (2000) 144–145.
[7] B.W. Trotman, R.D. Soloway, Pigment gallstone disease: summary of the National Institutes of Health–international workshop, Hepatology (Baltimore, Md) 2 (6) (1982) 879–884.
[8] R.A. Agha, T. Franchi, C. Sohrabi, G. Mathew, A. Kerwan, The SCARE 2020 guideline: updating consensus surgical CAse REport (SCARE) guidelines, Int. J. Surg. 84 (2020) 226–230.
[9] N. Suzuki, Toyoda MJTTjoem, in: On Infrared Absorption Spectra of Bilirubin and Calcium Bilirubinate 88(4), 1966, pp. 353–360.
[10] B.W. Trotman, T.A. Morris III, H.M. Sanchez III, R.D. Soloway III, J.D.J.G. Ostrow, in: Pigment Versus Cholesterol Cholelithiasis: Identification and Quantification by Infrared Spectroscopy 72(3), 1977, pp. 495–498.
[11] U. Gupta, V.K. Singh, V. Kumar, Y.J.M.F. Khajuria, in: Spectroscopic Studies of Cholesterol: Fourier Transform Infra-red and Vibrational Frequency Analysis 3(3), 2014, pp. 211–217.
[12] B.J. Ha, SJBr Park, in: Classification of Gallstones Using Fourier-transform Infrared Spectroscopy and Photography 22(1), 2018, pp. 1–8.
[13] T. Suo, P. Peng, M. Feng, H. Liu, Z. Ai, S. Tong, in: Fixed-point and Stratified Analysis of the Fine Structure and Composition of Five Gallstones With Fourier Transform Infrared (FT-IR) Specular Reflection Spectroscopy 75(3), 2012, pp. 294–299.
[14] W.H. Shehadi, The biliary system through the ages, Int. Surg. 64 (6) (1979) 63–78.
[15] D.M. Shabanzadeh, New determinants for gallstone disease? Dan. Med. J. 65 (2) (2018).
[16] N. Nakamura, Mucopolysaccharides and their significance in gallstone formation, Tohoku J. Exp. Med. 93 (3) (1967) 235–247.
[17] D.J. Sutor, L.I. Wilkie, Calcium in bile and calcium salts in gallstones, Clin. Chim. Acta 79 (1) (1977) 119–127.
[18] A. Sedaghat, S.M. Grundy, Cholesterol crystals and the formation of cholesterol gallstones, N. Engl. J. Med. 302 (23) (1980) 1274–1277.
[19] M.D. Stringer, R.D. Soloway, D.R. Taylor, K. Riyad, G. Toogood, Calcium carbonate gallstones in children, J. Pediatr. Surg. 42 (10) (2007) 1677–1682.
[20] L.M. Stinton, E.A. Shaffer, Epidemiology of gallbladder disease: cholelithiasis and cancer, Gut Liver 6 (2) (2012) 172–187.
[21] F. Angelico, M. Del Ben, A. Barbato, R. Conti, G. Urbinati, Ten-year incidence and natural history of gallstone disease in a rural population of women in central Italy. The Rome Group for the Epidemiology and Prevention of Cholelithiasis (GREPCO), Ital. J. Gastroenterol. Hepatol. 29 (3) (1997) 249–254.
[22] J.E. Everhart, M. Khare, M. Hill, K.R. Maurer, Prevalence and ethnic differences in gallbladder disease in the United States, Gastroenterology 117 (3) (1999) 632–639.
[23] A. Di Ciaula, D.Q. Wang, P. Portincasa, An update on the pathogenesis of cholesterol gallstone disease, Curr. Opin. Gastroenterol. 34 (2) (2018) 71–80.
[24] A. Cao, G. Eslick, in: Epidemiology and Pathogenesis of Gallstones, 2018, pp. 53–66.
[25] D.J. Cirillo, R.B. Wallace, R.J. Rodabough, P. Greenland, A.Z. LaCroix, M. C. Limacher, et al., Effect of estrogen therapy on gallbladder disease, JAMA 293 (3) (2005) 330–339.
[26] C. Thijs, P. Knipschild, Oral contraceptives and the risk of gallbladder disease: a meta-analysis, Am. J. Public Health 83 (8) (1993) 1113–1120.
[27] E.A. Shaffer, Epidemiology and risk factors for gallstone disease: has the paradigm changed in the 21st century? Curr. Gastroenterol. Rep. 7 (2) (2005) 132–140.
[28] K. Einarsson, K. Nilsell, B. Leijd, B. Angelin, Influence of age on secretion of cholesterol and synthesis of bile acids by the liver, N. Engl. J. Med. 313 (5) (1985) 277–282.
[29] H. Kameda, F. Ishihara, K. Shibata, E. Tsukie, Clinical and nutritional study on gallstone disease in Japan, Jpn. J. Med. 23 (2) (1984) 109–113.
[30] J.R. Thornton, P.M. Emmett, K.W. Heaton, Diet and gall stones: effects of refined and unrefined carbohydrate diets on bile cholesterol saturation and bile acid metabolism, Gut 24 (1) (1983) 2–6.
[31] N. Méndez-Sánchez, N.C. Chavez-Tapia, D. Motola-Kuba, K. Sanchez-Lara, G. Ponciano-Rodríguez, H. Baptista, et al., Metabolic syndrome as a risk factor for gallstone disease, World J. Gastroenterol. 11 (11) (2005) 1653–1657.
[32] C. Weikert, S. Weikert, M.B. Schulze, T. Pischon, A. Fritsche, M.M. Bergmann, et al., Presence of gallstones or kidney stones and risk of type 2 diabetes, Am. J. Epidemiol. 171 (4) (2010) 447–454.
[33] F. Nervi, J.F. Miquel, M. Alvarez, C. Ferreccio, M.J. García-Zattera, R. González, et al., Gallbladder disease is associated with insulin resistance in a high risk hispanic population, J. Hepatol. 45 (2) (2006) 299–305.
[34] J.E. Everhart, Contributions of obesity and weight loss to gallstone disease, Ann. Intern. Med. 119 (10) (1993) 1029–1035.
[35] M.H. Flasar, E. Goldberg, Acute abdominal pain, Med. Clin. N. Am. 90 (3) (2006) 481–503.
[36] A.K. Diehl, Symptoms of gallstone disease, Baillieres Clin. Gastroenterol. 6 (4) (1992) 635–657.
[37] L.M. Knab, A.M. Boller, D.M. Mahvi, Cholecystitis, Surg. Clin. North Am. 94 (2) (2014) 455–470.
[38] I. Fernández-López, D. Peña-Otero, M.D.L. Ángeles Atín-Arratibel, M. Eguillor-Mutiloa, Influence of the phrenic nerve in shoulder pain: a systematic review, Int. J. Osteopath. Med. 36 (2020) 36–48.
[39] J.Y. Lee, M.G. Keane, S. Pereira, Diagnosis and treatment of gallstone disease, Practitioner 259 (1783) (2015) 15–19.
[40] G. Sanders, A.N. Kingsnorth, Gallstones, BMJ (Clinical Research ed) 335 (7614) (2007) 295–299.
[41] I.J. Beckingham, S.D. Ryder, ABC of diseases of liver, pancreas, and biliary system. investigation of liver and biliary disease, BMJ (Clinical Research ed) 322 (7277) (2001) 33–36.
[42] V. Halpin, Acute cholecystitis, BMJ Clin. Evid. 2014 (2014).
[43] M. Ahmed, Acute cholangitis - an update, World J. Gastrointest. Pathophysiol. 9 (1) (2018) 1–7.

[44] M.X. Yan, Y.Q. Li, Gall stones and chronic pancreatitis: the black box in between, Postgrad. Med. J. 82 (966) (2006) 254–258.
[45] M. Gonzalez-Urquijo, M. Rodarte-Shade, G. Lozano-Balderas, G. Gil-Galindo, Cholecystoenteric fistula with and without gallstone ileus: a case series, Hepatobiliary Pancreat. Dis. Int. 19 (1) (2020) 36–40.
[46] R.E. Lawther, T. Diamond, Bouveret's syndrome: gallstone ileus causing gastric outlet obstruction, Ulster Med. J. 69 (1) (2000) 69–70.
[47] V. Mehta, G. Yarmish, J. Greenstein, B. Hahn, Gallbladder empyema, J. Emerg. Med. 50 (6) (2016) 893–894.
[48] S. Ryu, Y. Chang, K.E. Yun, H.S. Jung, J.H. Shin, H. Shin, Gallstones and the risk of gallbladder cancer mortality: a cohort study, Am. J. Gastroenterol. 111 (10) (2016) 1476–1487.
[49] J.J.S. Kiewiet, M.M.N. Leeuwenburgh, S. Bipat, P.M.M. Bossuyt, J. Stoker, M. A. Boermeester, A systematic review and meta-analysis of diagnostic performance of imaging in acute cholecystitis, Radiology 264 (3) (2012) 708–720.
[50] G. Burmeister, S. Hinz, C. Schafmayer, Acute cholecystitis, Zentralbl. Chir. 143 (4) (2018) 392–399.
[51] C.B. Yang, S. Zhang, Y.J. Jia, H.F. Duan, G.M. Ma, X.R. Zhang, et al., Clinical application of dual-energy spectral computed tomography in detecting cholesterol gallstones from surrounding bile, Acad. Radiol. 24 (4) (2017) 478–482.
[52] N.J. Schepers, N.D.L. Hallensleben, M.G. Besselink, M.G.F. Anten, T.L. Bollen, D. W. da Costa, et al., Urgent endoscopic retrograde cholangiopancreatography with sphincterotomy versus conservative treatment in predicted severe acute gallstone pancreatitis (APEC): a multicentre randomised controlled trial, Lancet (London, England) 396 (10245) (2020) 167–176.
[53] S.N. Hochwald, M.B. Dobryansky, N.M. Rofsky, K.S. Naik, P. Shamamian, G. Coppa, et al., Magnetic resonance cholangiopancreatography accurately predicts the presence or absence of choledocholithiasis, J. Gastrointest. Surg. 2 (6) (1998) 573–579.
[54] S.S. Wang, X.Z. Lin, Y.T. Tsai, S.D. Lee, H.B. Pan, Y.H. Chou, et al., Clinical significance of ultrasonography, computed tomography, and biochemical tests in the rapid diagnosis of gallstone-related pancreatitis: a prospective study, Pancreas 3 (2) (1988) 153–158.
[55] M. Elshaer, G. Gravante, K. Thomas, R. Sorge, S. Al-Hamali, H. Ebdewi, Subtotal cholecystectomy for "difficult gallbladders": systematic review and meta-analysis, JAMA Surg. 150 (2) (2015) 159–168.
[56] M.A. Machado, P. Herman, A simple technique for removal of the gallbladder during microlaparoscopic cholecystectomy, Surg. Endosc. 18 (8) (2004) 1289–1290.
[59] B.W. Trotman, R.D. Soloway, Pigment vs cholesterol cholelithiasis: clinical and epidemiological aspects, Am J Dig Dis 20 (8) (1975) 735–740.
[60] A.F. Attili, R. Capocaccia, N. Carulli, D. Festi, E. Roda, L. Barbara, et al., Factors associated with gallstone disease in the MICOL experience. Multicenter Italian Study on Epidemiology of Cholelithiasis, Hepatology (Baltimore, Md) 26 (4) (1997) 809–818.
[61] A.K. Diehl, Epidemiology and natural history of gallstone disease, Gastroenterol. Clin. N. Am. 20 (1) (1991) 1–19.
[62] A.F. Attili, N. Carulli, E. Roda, B. Barbara, L. Capocaccia, A. Menotti, et al., Epidemiology of gallstone disease in Italy: prevalence data of the multicenter italian study on cholelithiasis (M.I.COL.), Am. J. Epidemiol. 141 (2) (1995) 158–165.
[63] O. Kleiner, J. Ramesh, M. Huleihel, B. Cohen, K. Kantarovich, C. Levi, et al., A comparative study of gallstones from children and adults using FTIR spectroscopy and fluorescence microscopy, BMC Gastroenterol. 2 (2002) 3.
[64] P. Stoner, A. Schlachterman, E. Hilgenfeldt, P. Draganov, Pearl-white gallstones causing choledocholithiasis, ACG case reports journal. 5 (2018), e4.