

EDITORIAL

The Pancreas and Respiration: Oblivious to the Obvious!

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“There is nothing more deceptive than an obvious fact”

Sir Arthur Conan Doyle (1859-1930)

From “The Boscombe Valley Mystery”, 1891

In the history of medicine, the pancreas was ignored both as an organ and as a site of disease because of its hidden retroperitoneal location [1]. Herophilus of Chalcedon first described the pancreas about the year 300 B.C. About four hundred years later in 100 A.D., Rufus of Ephesus named the organ the pancreas (from the Greek *pan*: all and *Kreas*: flesh or meat) [1, 2, 3]. In contrast to a prior belief that it is nothing more than a cushion behind the stomach to protect the major blood vessels, the pancreas now occupies the position of a vital organ with important endocrine and exocrine functions. Advances in understanding the anatomy and the physiology of pancreas, and in the diagnosis and treatment of pancreatic diseases have come a long way since its first historical description [1].

The pancreas has classically been described as a retroperitoneal fixed organ within the loop of the duodenum [4]. It is a soft, lobulated, greyish-pink gland weighing about 70 to 100 grams. It lies transversely in the retroperitoneum, across the posterior abdominal wall, between the duodenum and the spleen. Due to its deep retroperitoneal location, being anchored within the C-loop of the duodenum and being delimited above by the origin of the celiac axis from the aorta, the pancreas and the swellings arising from it were considered to be immobile on

respiration [4, 5, 6, 7, 8]. In contrast, intraperitoneal organs such as the liver and the spleen and the swellings arising from them have been shown to move considerably with respiration because of their intraperitoneal location and close proximity to the diaphragm [5].

The motion of the upper abdominal intraperitoneal organs, like the liver during respiration has been studied extensively because this respiratory movement poses a significant obstacle to the precise percutaneous placement of needles or catheters in percutaneous radiological interventions [9, 10]. The movement of these organs with respiration has been shown to be a complex phenomenon with a combination of cranio-caudal, lateral and anterior-posterior motion along with movement due to the elasticity of the tissue being responsible for the final composite movement during respiration [9].

However, due to the prior belief that the pancreas is a fixed retroperitoneal organ, no attention was paid to the movement of the pancreas during respiration and its possible clinical implications. With the advent of new imaging modalities, radiologists have noticed that the pancreas and pancreatic lesions move not only with respiration but also with a change in posture. On several occasions while performing endoscopic retrograde pancreatography (ERP), we noted, under fluoroscopy, the movement of a contrast-filled pancreatic duct during respiration. This prompted our study about the extent of pancreatic movement with respiration, using a

simple and inexpensive method of fluoroscopy [11].

Since the 1980's, the phenomenon of pancreatic mobility has been recognized and various authors using different imaging modalities have described the varying extent of pancreatic mobility during respiration and change of posture. Suramo *et al.* [12] studied the cranio-caudal movement of pancreas using computed tomography (CT) and real time ultrasonic scanner with linear transducer. They first exposed 70 consecutive patients, two or more times, in abdominal CT examination at precisely the same level. The patients were breathing in between the exposures. The respiratory phase was kept constant in these patients after repeated rehearsals. The liver was examined in 28 patients, the pancreas in 17 patients and the kidneys in 25 patients. The body and the tail of the pancreas were situated at significantly different cranio-caudal levels in two identically exposed CT slices, in 20% and 43% of the patients, respectively. In comparison, the liver and the kidneys were markedly varied in their position in 25% and 20% of the patients, respectively. The tail of the pancreas was noted to have the maximum mobility. Thereafter, in another 50 patients, using linear array ultrasound the authors recorded the movement of the cranial margin of the body of the pancreas along with the caudal margin of the right lobe of the liver and both kidneys during deep and normal inspiration and expiration. The mean movement of the body of the pancreas on normal respiration was 2.0 cm (range: 1 to 3 cm) and was 4.3 cm (range: 2 to 8 cm) on maximum respiration. The mean movement (range) of the liver, the right kidney and the left kidney on maximum respiration was 5.5 cm (3-8 cm), 4 cm (2-7 cm) and 4.1 cm (2-7 cm), respectively; it was 2.5 cm (1-4 cm), 1.9 cm (1-4 cm) and 1.9 cm (1-4 cm), respectively on normal respiration. The pancreas moved more than the kidney but less than the liver.

Bryan *et al.* [13], using ultrasound, documented the movement of the pancreas from full inspiration to full expiration in the

plane of the superior mesenteric artery in supine, prone and lateral decubitus positions in 36 normal patients. The respiratory excursion ranged from 0 to 3.5 cm with mean movements being 1.8, 1.9 and 2.2 cm in supine, prone and lateral decubitus, respectively. Morgan and Dubbins [14], using ultrasound, studied the position of the pancreas and the right kidney in supine and left posterior oblique positions in 145 patients undergoing ultrasound examination for unrelated symptomatology. The scans were performed in the sagittal and transverse planes. It was noted that with a change in patient position, the pancreas moved in 37.5% of the patients and the right kidney in 6.6% of the patients. This alteration in position was seen more often in females and affected all age groups equally. The pancreas was observed to move from a few millimeters to several centimeters to the left of the aorta.

Kivisaari *et al.* [15] studied pancreatic mobility in 28 consecutive patients (19 with a normal pancreas, 7 with chronic pancreatitis and 2 with pancreatic head cancer). Following endoscopic retrograde pancreatography (ERP), the upper abdomen was radiographed in normal inspiration and expiration. The movement of the contrast filling the pancreatic duct was measured in the head, body and tail regions of the pancreas in relation to the lumbar vertebra. The tail of the pancreas was the most mobile part with a maximum movement of 8.8 cm. In patients with a normal pancreas, chronic pancreatitis and pancreatic head cancer, the mean (range) movement of the tail of the pancreas was 4.1cm (0.5-8.8 cm), 3.2 cm (0.9-5.1 cm) and 1.4 cm (1-1.8 cm), respectively, the movement of the body was 3.0 (0.9-6.2 cm), 2.9 (0.6-4.4 cm) and 2.5 cm (2.4-2.6 cm), respectively, and the movement of the head was 3.2 cm (0.9-5.6 cm), 3.2 cm (1.4-4.5 cm) and 2.2 cm (1.8-2.6 cm), respectively.

Bussels *et al.* [16] reported movement of the pancreas during respiration with dynamic magnetic resonance imaging in a supine position in 12 subjects (6 with a normal pancreas and 6 with a pancreatic tumor). The movement of the pancreatic tumor or the head

of the pancreas in the cranio-caudal, lateral and anterior-posterior direction was calculated from the movement of the centre of gravity on two-dimensional images. The mean (\pm SD) cranio-caudal, anterior-posterior and lateral movements of the pancreas were 2.37 ± 1.59 cm, 0.60 ± 0.34 cm and 1.21 ± 0.9 cm, respectively. The cranio-caudal movements for the liver, the right kidney and the left kidney were 2.44 ± 1.64 cm, 1.61 ± 0.79 cm and 1.69 ± 0.67 cm, respectively. This study also corroborated the earlier observation that the pancreas was more mobile than the kidneys.

In our study, using simple, inexpensive and easy to understand techniques, we have confirmed that the pancreas does indeed move during respiration [11]. We studied pancreatic mobility in 22 patients (17 males, 5 females; age: 35.5 ± 11.3 years, mean \pm SD) with chronic pancreatitis (10 patients with parenchymal calcification evident on fluoroscopy and 12 patients with an indwelling pancreatic duct stent). Under fluoroscopy, the position of the stent or pancreatic calcification was recorded during maximum inspiration followed by maximum expiration. The movement of the head, body and tail of the pancreas in a cranio-caudal direction was analyzed by measuring the displacement of the stent or calcification. In addition, the medial movement of the head was also recorded. The vertebral column was used as the fixed landmark for the measurements. In patients with pancreatic calcification, on maximum inspiration, the pancreas moved downward in the cranio-caudal direction in all ten patients whereas the medial movement of the head was noted in 6 out of 7 (85.7%) patients. The mean (range) cranio-caudal movement of the head, body and tail of the pancreas was 1.28 cm (0.3-2.1 cm), 0.47 cm (0.1-0.8 cm) and 1.34 cm (0.5-2.1 cm), respectively whereas the mean (range) medial movement of the head was 0.15 cm (0.0-0.4 cm). In patients with an indwelling pancreatic duct stent, on maximum inspiration, the pancreas moved downward in a cranio-caudal direction in all twelve patients whereas the medial movement of the head was noted in 11 out of 12 (91.7%)

patients. The mean (range) cranio-caudal movement of the head, body and tail of the pancreas was 1.44 cm (0.1-2.8 cm), 1.37 cm (0.1-2.6 cm) and 1.12 cm (0.1-3.4 cm), respectively whereas the mean (range) medial movement of the head was 0.42 cm (0.0-2.0 cm). The mean movements of the pancreas in our study were less than those reported in the literature [12, 13, 14, 15, 16]. These differences may be due to the fact that all of our patients had chronic pancreatitis and chronic inflammation, and peripancreatic fibrosis may have restricted pancreatic mobility and caused asymmetrical movements. In our study, although the sample size was small, there was no significant difference in pancreatic mobility with age, sex, etiology of underlying chronic pancreatitis, presence or absence of pancreatic calcification, severity of ductal changes of chronic pancreatitis and the length or the diameter of the pancreatic duct stent used. Bussels *et al.* [16] also did not find any correlation between the movement of the pancreas and age, sex, weight and body mass index. However, Morgan and Dubbins [14] found that the incidence of pancreatic mobility on changing position from a supine to a left posterior oblique position was more common in females. Similarly, Suramo *et al.* [12] showed that the displacement of the pancreas in maximum respiration was shorter by 1 cm in subjects over 60 years of age in comparison to those under 60 years of age. The changes in the pancreas during respiration are not limited to cranio-caudal or lateral movements but the pancreatic ductal diameter has also been shown to increase with inspiration [17]. On sonography, the upper limit of the pancreatic duct diameter in the body of the pancreas is 2.5 mm [18]. Wachsberg [17] measured the diameter of the pancreatic duct in 25 consecutive lean patients who had normal abdominal sonographic findings. The antero-posterior diameter of the pancreatic duct in the body was measured at end-expiration and end-inspiration. A significant change was defined as a 1 mm or greater difference between the end-inspiratory and end-expiratory diameters

for at least two of three consecutive breaths. The mean diameter of the pancreatic duct at end-expiration was noted to be 1.2 mm (range: 0.7-2.0 mm). A significant increase in the diameter of the duct after inspiration was observed in seven patients (28%), with a mean increase of 1.3 mm (range: 1.0-2.2 mm). These seven included four patients (16%) in whom the diameter of the duct was less than or equal to 2.5 mm (i.e., normal) at end-inspiration and three patients (12%) in whom the diameter of the duct was greater than 2.5 mm at end-inspiration. The diameter of the pancreatic duct exceeded the upper limit of normal at end-inspiration in 12% of patients who otherwise had no evidence of pancreatic disease and also in whom the end-expiratory diameter of the duct was normal. The author postulated that this increase in the diameter of the pancreatic duct could be due to a medial movement of the pancreatic tail during inspiration which might result in the shortening of the long axis dimension of the pancreas. This would shorten the length of the pancreatic duct because the duct is entirely surrounded by the pancreatic parenchyma and spans the length of the gland. To accommodate the pancreatic fluid in the lumen of the duct, a decrease in the length of the duct would necessitate a concomitant increase in its diameter if the pancreatic sphincter remained closed [17]. This phenomenon could be of importance in secretin-enhanced imaging modalities especially if the pre-secretin and post-secretin images were taken in different phases of respiration.

These movements of the pancreas with respiration may have important clinical implications for static B-mode ultrasound scanning and computed tomography scanning. The cranio-caudal and dorsoventral diameters of the pancreas are 3-5 cm and 2-3 cm, respectively [19]. As shown earlier, the cranio-caudal movement of the pancreatic tail may reach up to 9 cm, which is three times the width of the tail and, therefore, the tail of the pancreas may not be visible on a computerized tomography (CT) scan if respiration is poorly controlled. However,

with the availability of new ultra fast CT scanners, these respiratory movements may not be a problem because of the fast image acquisition. It will be important to consider the movement of the pancreas with respiration when focusing on pancreatic duct stones during treatment with extracorporeal shockwave lithotripsy (ESWL). It is necessary to have proper breath holding sessions in the same phase of respiration for accurate focusing and fragmentation of pancreatic stones.

Similarly, the movement of the pancreas on respiration can interfere with the accurate placement of the needle during percutaneous fine needle aspiration biopsy and other minimally invasive interventions. Accuracy requirements are going to be more stringent as the targets for percutaneous therapy become smaller and smaller such as in gene therapy for micro-metastasis. Precise targeting will be required for novel therapeutic procedures such as ablations, anti-angiogenesis and gene therapy; it will be interesting to see the impact of the movement of the pancreas on respiration on implementation of these treatment strategies in the field of pancreatology.

Pancreatic mobility may also have an important bearing on the treatment strategies for pancreatic cancer. Pancreatic cancer has a dismal prognosis [20] and a number of newer approaches are being studied to improve the prognosis of this grave malignancy. Advanced radiation techniques, such as three-dimensional conformal radiotherapy or intensity modulated radiation therapy, are being used in the treatment of pancreatic cancer [21, 22]. When these techniques are used, it is important to accurately delineate the tumor volume and its extension, taking into account patient movement as well as organ movement on respiration [21, 22]. This is essential because the pancreas may move during respiration, resulting in normal tissues getting a radiation overdose and the targeted areas getting an insufficient radiation dose, leading to treatment failure.

Although in the modern era of advanced imaging technologies, clinical bedside

medicine has taken a back seat and is slowly becoming extinct; in our opinion, it should be preserved as a heritage and as an art and still remain a front runner for the comprehensive management of patients. Hence, it would also be interesting to study the implications of the movement of the pancreas during respiration on the teachings of clinical medicine and the differential diagnosis between swellings of the pancreas and other intra-abdominal swellings.

In conclusion, our study, as well as other studies using different imaging techniques, have dispelled the traditional belief that the pancreas does not move on respiration. The pancreas does indeed move during respiration! The time has come for us to recognize the clinical significance and implications of this, as we march towards new frontiers in the management of pancreatic diseases.

Keywords Biopsy, Needle; Cholangio-pancreatography, Endoscopic Retrograde; Education, Medical; Endosonography; Lithotripsy; Magnetic Resonance Imaging; Pancreatic Neoplasms; Pancreatitis; Tomography, X-Ray Computed; Ultrasonography

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References

1. Busnardo AC, DiDio LJ, Tidrick RT, Thomford NR. History of the Pancreas. *Am J Surg* 1983; 146:539-50. [PMID 6356946]
2. Fitzgerald PJ. Medical anecdotes concerning some diseases of the pancreas. In: Fitzgerald PJ, Morrison AB, eds. *The Pancreas*, Baltimore P, USA: Williams and Wilkins, 1980:1-29.

3. Major RH. *A History of Medicine*. Springfield: Charles C Thomas, 1954:182:503-4.
4. Williams PL, Warwick R, Dyson M, Bannister LH, eds. *Gray's Anatomy*. 37th edition. Edinburgh, UK: Longman Group, 1989; 1380-4.
5. Swain P. The gastrointestinal tract and abdomen. In: Swash M, ed. *Hutchison's Clinical Method's*. 20th edition, London: W.B. Saunders, 1995:75-116.
6. Clain A, ed. Non acute abdominal conditions. In: Hamilton Bailey's *Demonstration of Physical Sign's in Clinical Surgery*. 17th ed. Bristol, United Kingdom: IOP Publishing Ltd., 1986:228-49.
7. Ogilvie C, Evans CC, eds. *The Digestive System*. In: Chamberlain's *Symptoms and Signs in Clinical Medicine*. 11th ed. Bristol, United Kingdom: IOP Publishing Ltd. 1987:65-130.
8. Vakil JR, Golwala AF, eds. *The Abdomen*. In: *Clinical Diagnosis*. 2nd ed. Mumbai, India: Asia Publishing House, 1967:370-405.
9. Clifford MA, Banovac F, Levy E, Cleary K. Assessment of hepatic motion secondary to respiration for computer assisted interventions. *Comp Aid Surg* 2002; 7:291-9. [PMID 12582982]
10. Davies SC, Hill AL, Holmes RB, Halliwell M, Jackson PC. Ultrasound quantitation of respiratory organ motion in the upper abdomen. *Br J Radiol* 1994; 67:1096-102. [PMID 7820402]
11. Bhasin DK, Rana SS, Jahagirdar S, Nagi B. Does the pancreas move with respiration? *J Gastroenterol Hepatol* 2006; 21:1424-7. [PMID 16911687]
12. Suramo I, Päivänsalo M, Myllylä V. Cranio-caudal movements of the liver, pancreas and kidneys in respiration. *Acta Radiol Diagn (Stockh)* 1984; 25:129-31. [PMID 6731017]
13. Bryan PJ, Custar S, Haaga JR, Balsara V. Respiration movement of the pancreas: an ultrasonic study. *J Ultrasound Med* 1984; 3:317-20. [PMID 6748150]
14. Morgan RA, Dubbins PA. Pancreatic and renal mobility. *Clin Radiol* 1992; 45:88-91. [PMID 1737435]
15. Kivisaari L, Makela P, Aarimaa M. Pancreatic mobility: an important factor in pancreatic computed tomography. *J Comput Assist Tomogr* 1982; 6:854-6. [PMID 7119215]
16. Bussels B, Goethals L, Feron M, Bielen D, Dymarkowski S, Suetens P, Haustermans K. Respiration-induced movement of the upper abdominal organs: a pitfall for the three-dimensional conformal radiation treatment of pancreatic cancer. *Radiother Oncol* 2003; 68:69-74. [PMID 12885454]

17. Wachsberg RH. Respiratory variation of the diameter of the pancreatic duct on sonography. *AJR Am J Roentgenol* 2000; 175:1459-61. [PMID 11044063]
 18. Atri M, Finnegan PW. The pancreas. In: Rumack CM, Wilson SR, Charboneau JW, eds. *Diagnostic Ultrasound*, 2nd ed. St. Louis, USA: Mosby-Year Book, 1998:225-77.
 19. Robbins SL, ed. *Pathologic Basis of Disease*. Philadelphia, USA: Saunders, 1974:1056-57.
 20. Warshaw AL, Fernandez-del Castillo C. Pancreatic carcinoma. *N Engl J Med* 1992; 326:455-65. [PMID 1732772]
 21. Chu JCH, Lawrence JS, Chin CH, Kessler H, Hanks GE. Three-dimensional dosimetric comparison of radiation therapy treatment planning of the pancreas. *Med Dosim* 1993; 17:199-203. [PMID 1485907]
 22. Higgins PD, Sohn JW, Fine RM, Schell MC. Three-dimensional conformal pancreas treatment: comparison of four- to six-field techniques. *Int J Radiat Oncol Biol Phys* 1995; 31:605-9. [PMID 7852126]
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