Paediatric Surgery Case

Authors: *Peter Calleja, Luke Camilleri*

Abstract

A complicated type of paediatric surgery case as reviewed in this paper consists of a neonate with two special types of GI atresias; a duodenal atresia (DA) and oesophageal atresia (OA) with distal tracheo-oesophageal fistula (TEF). Atresia can be defined as the congenital absence or obstruction of a normally patent lumen or orifice. While most small and large bowel atresias are thought to be due to ante-natal ischaemic events (vascular insult hypothesis), DA is due to a failure of duodenal recanalization around the 4th to 10th week of gestation. OA/TEF arises from a defect in the formation of the tracheo-oesophageal septum.

The patient was prenatally diagnosed with DA via the double bubble sign on ultrasound. Post natally, an attempted nasogastric (NG) tube insertion failed and coiled , confirming OA. The double bubble sign being present simultaneously (such as in DA) therefore indicated a connection between the oesophagus and the trachea such that air is blown into the stomach despite the OA. This is how the TEF was diagnosed , and both conditions necessitate immediate surgical intervention in the first 24 hours of birth.

Surgical goals involve fistula ligation , division and restoration of continuous lumen. The standard procedure for OA/TEF (most commonly type C) is primary repair via thoracotomy or thoracoscopy, with end to end anastomosis. DA is primarily repaired via duodeno-duodenostomy, using the Diamond shaped (Kimura) procedure/anastomosis. The management includes pre and post operative care , utilising a replogle tube for suction and sham feeding to maintain oral motor skills and gut stimulation , feeding prior to oral feeds is done with total parenteral nutrition. Post op following both repairs a transanastomotic tube is inserted where the duodenum dilates , in order to allow for the dilation to repair bypassing the surgical site in the meantime. Post operative complications include anastomotic leakage , structures , motility issues and increased risk of chronic issues. Associated conditions like VACTERL association and Downs syndrome are important risk factors for consideration in these patients.

List of Abbreviations

Abbvrebiation	Defintion
DA	Duodenal Atresia
Oesophageal Atresia	OA/EA
Tracheo-oesophageal Fistula	TEF

Nasogastric	Defintion
Ultrasound	US
Gastrointestinal	GI
Diamond-shaped	DS
Transanastomotic tube	TAT
Total Parenteral Nutrition	TPN
Gastroesophageal Reflux disease	GORD/GERD
Intravenous	IV
Oesophagogastroduodenoscopy	OGD

List of Figures

List of Tables

General information on Atresia / Introduction

What is atresia: (2)(3)

By definition, atresia refers to obstruction or congenital absence of a lumen or orifice which is normally patent within the body.

This occurs most commonly due to a congenital malformation following an ante-natal ischaemic event. In the case of the two special atresias present in the patient to be discussed, they arise from different causes.

In paediatric surgery, it is common to encounter gastro-intestinally related atresias which are the focus of this paper, however atresia can also be biliary, cardiovascular and urogenital amongst others.

Embryology: Vascular-insult hypothesis, Failure of recanalization and Defective Partitioning.

A volvulus, thrombo-embolic event, or intussusception that occur in-utero to the foetus, which fall under the vascular insult hypothesis, are all common culprits for atresia to occur within the G.I tract, particularly the small and large bowels. (15)

For duodenal atresia, vascular insult is not the cause, instead during embryological development failure of recanalization can occur. In absence of pathology, the duodenal lumen becomes occluded by endodermal epithelium at around the 4th to 6th week of development. At around the 8th to 10th week, the lumen undergoes recanalization to maintain patency. If this stage fails to be completed, atresia ensues. (4) Failure to regain patency may be due to epithelial over-proliferation, reduced apoptosis of gut epithelium or defects in particular molecular signaling pathways, such as that involving the SHH protein. (7)(8)

The tracheo-oesphageal fistula present in this patient is another special type as it occurs due to an abnormality in the process of formation of a tracheo-oesophageal septum. In normal circumstances, this septum divides the embryological foregut into a ventral tube, that eventually gives rise to the trachea, and a dorsal tube which becomes the oesophagus. Failure of this process can lead to OA with distal TEF (5), the most common outcome of septal failure and is the same issue observed in the neonate discussed. Less commonly, isolated OA or isolated TEF can occur, the latter also known as H-type fistula. (3)(4)(5)

General types of atresia in the G.I tract:

Generally, atresias can be found on a spectrum of complexity regarding the required surgical management. This general classification below mainly applies to most small and large bowel atresias, and is referred to as the Louw and Barnard classification. This is because upper G.I examples like duodenal and oesophageal atresias have their own allocated subtypes. (6)

Solely using medical management will not provide any path for improvement in any of these cases, hence surgical intervention is always required in synergy with medications.

-Regarding the two special types of atresia in the neonatal patient being discussed, their embryological development, their distinct genetic risk factors, and anatomical position give them different clinical significance when compared to the general classification of G.I atresias and hence require a tailored surgical approach. Their separate classifications are discussed later on. (6)(9)(14)

Case Presentation

-The patient, a neonate, was found pre-natally to

Table 1: General types of atresia (3)(5)

Type of Atresia	Description	Key Features	Relative Complexity
Type I: Mucosal / Web Type	A mucosal diaphragm or web obstructs the lumen; bowel wall continuity is intact.	Thin membrane; may have a central perforation ("windsock" deformity).	Least complex.
Type II: Fibrous Cord Type	Two blind-ending bowel segments are connected by a fibrous cord; mesentery is usually intact.	Serosa and mesentery continuous; no bowel gap; vascular supply preserved.	Low comlpexity.
Type IIIa: Complete Discontinuity	Complete separation of proximal and distal bowel; a mesenteric gap is present.	V-shaped mesenteric defect; loss of some blood supply to distal segment likely.	Moderate complexity.
Type IIIb: 'Apple-peel' Atresia	Proximal jejunal atresia with distal small bowel spiralling around a marginal artery.	"Christmas tree" appearance; extensive bowel loss; reduced mesentery.	High complexity.
Type IV: Multiple Atresias	Several atretic segments throughout the bowel, resembling a "string of sausages'.	Multiple discontinuities; significant risk of short bowel syndrome.	Most complex.

have the double-bubble sign on abdominal US of the mother, indicating duodenal atresia. This was further confirmed post-natally via abdominal X-ray of the neonate which showed similar radiological findings.

-An emergency NG tube insertion was attempted but unsuccessful for the first few attempts. Once supposedly inserted, another X-ray was taken to confirm the NG tube was correctly positioned, however the image showed that the tube curved upwards which was indicative of oesophageal atresia

-Due to the presence of gas within the stomach and duodenum, a fistula was suspected and this prompted further investigation via tracheoscopy.

-Tracheoscopy revealed the presence of a tracheo-oesophageal fistula, the other culprit of this emergency case.

-Note Maternal History of non smoker , non drinker , no history of Downs syndrome , overweight

- Must be operated within 24hrs of life

Guidelines And Management

Bypassing Oesophageal Atresia and closure of TEF: (23)

-The goals of EA/TEF surgery are the ligation and division of the fistula and the restoration of esophageal continuity via anastomosis. For the highly prevalent Type C ref, primary repair is usually performed through an opening on the side of the chest (thoracotomy or thoracoscopy). The surgeon first separates the trachea and esophagus, closes the fistula, and then proceeds to suture the upper and lower esophageal segments together. (9)(16)(17)

-Regarding preparation of oesophageal anastomosis, the upper pouch should be mobilized enough to avoid tension due to anastomosis. The lower end must also be mobilized to gain length. It is essential to preserve arterial supply to the oesophagus during this process. (18)(19)

-End-to-end anastomosis is performed, and depending on the gap's length being shorter or longer than 3cm, different techniques are applied. For short-gap OA (3cm or shorter), interrupted absorbable sutures are used starting from the posterior wall (21)(22). An NG tube is then placed along the anastomosis. Ensure the anastomosis is free from tension.

-Long-gap OA, which ranges from 3cm to approximately 5cm, requires the Foker techniques (21) which involves silastic traction sutures. These sutures are placed in each end of the segmented oesophagus and are externalized through the neonate's chest wall to be attached to a tension device. The tension applied is maintained over days and allows elongation of the oesophageal ends to gradually grow towards one another. Once the gap reaches a feasible length with which tension-free anastomosis can be done, that is the procedure performed for short-gap OA, the oesophageal ends are sutured together. (21, 22)

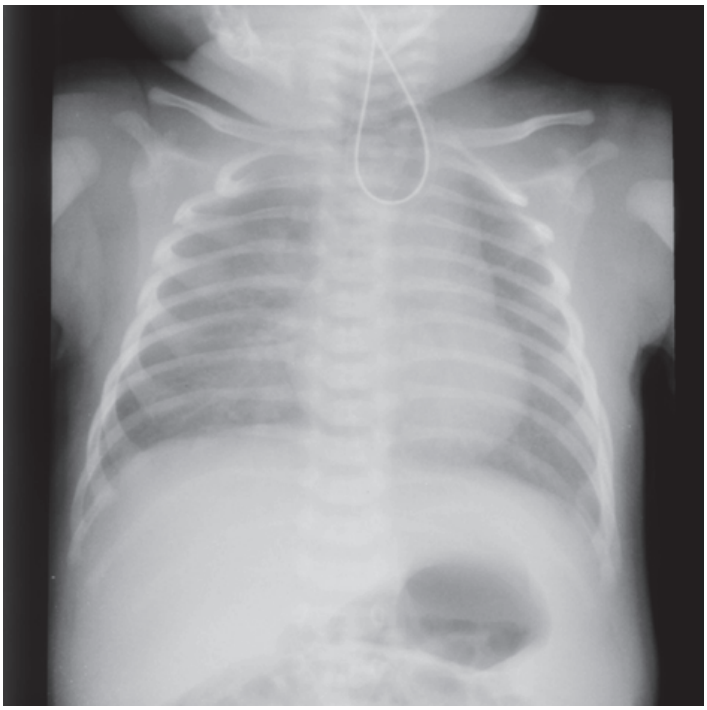

Figure 1: Showing nasogastric tube looping in the case of OA with associated TEF (7)

Bypassing Duodenal Atresia: (8)(10)(24)

-Correct electrolyte imbalance and dehydration.
-Open surgical approach was the only approach available before, however minimally invasive techniques are now being used more frequently. Primarily a Duodeno-duodenostomy is performed, or alternatively a duodeno-jejunostomy. (24)

-Duodeno-duodenostomy can involve either of two modern techniques: Diamond-shaped (DS) group or Side-to-side (STS) group. Similar recovery time and surgical outcome was noted between the two. In Malta, DS technique is preferred. (25)(26)
-These surgical procedures can be performed, via micro-incisions of approximately 3mm, through a laparoscopic view of the abdominal contents.

-The Diamond-shaped Duodeno-duodenostomy is also known as the Kimura anastomosis. Kimura has better outcomes for all types of DA, however in type I simply a duodenotomy may work if the web is thin. If a thin web or membrane is present,

-an anterior longitudinal incision is made along the proximal side of the duodenal obstruction. The membrane is then circumferentially excised with careful attention of avoiding damage to the postero-medial wall where the Ampulla of Vater is located. Duodenectomy is then closed transversely. (24 - 26)

-Regarding the Kimura procedure, firstly duodenal mobilization is performed which is also referred to as the Kocher manoeuvre, and in type III is required to be more extensive in order to allow for a tension-free anastomosis. In type II, the fibrous cord must be excised. A longitudinal incision on the proximal side of the atresia and a transverse one on the distal side are then created. These two incisions are brought together, while ensuring there is no tension, to create a diamond-shaped lumen. (24-26)

-Rarely, if the gap in type III DA is significant enough that extensive mobilisation is insufficient, a duodenojejunostomy must be performed.

-In cases where the distal lumen is too small to create a transverse incision on it, or where there is a large proximal bulb, the Reverse Kimura technique is utilised to avoid a distorted anastomosis. The only difference in this procedure when compared to the standard Kimura anastomosis is that a transverse incision is made in the proximal end and a longitudinal one for the distal end, hence the opposite of the standard. (25)

Feeding Management

1. Before OA / TEF repair:

-Reprogle tube: is comprised of a double-lumen tube which is soft and flexible. Through one lumen, suction pressure is applied to drain secretions (saliva in OA and gastric juice in duodenal atresia), while the other pumps in air to prevent mucosal trauma caused by the suction. This allows for safe prevention of aspiration pneumonia (tube placed in blind end of the proximal oesophagus). For duodenal atresia in isolation, the Replogle tube can

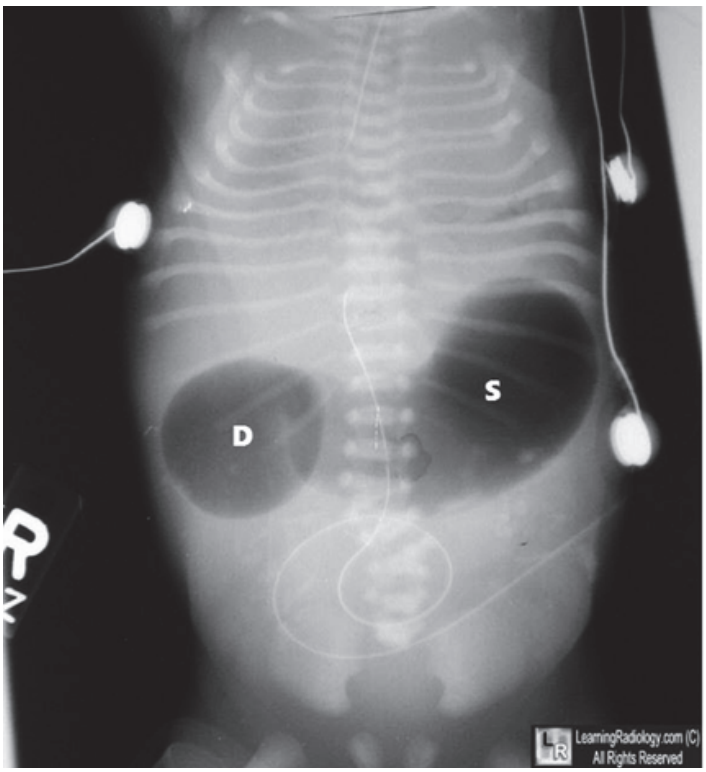

Figure 2: Showing the double bubble sign in duodenal atresia (7)

-be used for suction of excess secretions from causing gastric distention by placing the tube-end in the stomach. However, the latter cannot be done in this particular neonate due to the repaired OA requiring recovery first before passing any tube through the oesophagus. (27)

- Sham feeding: is essentially the act of the baby sucking and swallowing a small amount of liquid, but the liquid is removed or drained before it reaches the blocked part of the GI tract. (in gastrostomy like in this case) (28)

2. After OA/TOF repair: (26 , 27 , 28, 23 , 22)

-IV TPN: No enteric feeding yet as the repaired OA requires time to heal, and duodenal atresia is still present.

-Keep Replogle tube and Sham feeding during recovery period of the new anastomosis, typically 3 to 5 days is a safe time. This is to maintain oral-motor practice and gut stimulation.

Table 2 : Summarisation of Sham feeding (27,28)

Step	Rationale
1. Sucking/Swallowing	Allows the infant to practice the fundamental oral motor skills and triggers the initial stages of digestion.
2. Stimulation of Digestive Juices:	The smell, taste, and swallowing of the milk stimulate the release of natural hormones and digestive juices (like saliva, gastric acid, and pancreatic enzymes).
3. Fluid Drainage/Removal:	Because of the atresia (blockage), the milk cannot safely pass. In esophageal atresia, the milk may be drained from the blind-ending upper pouch via Replogle tube. After OA/TOF is repaired and anastomosis recovers, gastrostomy is used to drain the milk.

-If there is risk of excessive stomach distension before DA repair is performed, gastrostomy is applied.

-If safe to do so, Replogle tube is removed after recovery of OA anastomosis.

3. After DA repair: (26 , 27 , 28, 23 , 22)

-Sham feeding is continued, however gastrostomy is inserted in order to vent distention and any liquid from sham feeding that reaches the stomach. IV TPN is continued.

-Keep Sham feeding and IV TPN until duodenum regains its function for about 5-10 days

4, Transition to oral feeds from Sham feeding: (27)

-Once OA/TOF anastomosis has properly recovered and duodenum is functioning - first feed with enteric tubing like Transpyloric feed, if tolerated then begin small oral feeds. Total recovery time including OA/TOF is about 2 weeks.

Post-Operative Complications: (29) (17)(9)

-Despite advances in surgical technique, acute complications can occur. Anastomotic leakage, where fluids or air escape the suture line, occurs in approximately 17% of surgeries . Most leaks resolve spontaneously with chest tube drainage, but they significantly increase the risk of long-term esophageal stricture and recurrent TEF. (30)

-Damage to surrounding structures, such as the recurrent laryngeal nerve (leading to vocal cord paralysis and aspiration risk) or the phrenic nerve (leading to diaphragm paralysis), is a rare but serious complication

-Infection

-Intraabdominal bleeding

-Anastomotic leak or stricture (leakage of connection site or constriction of repaired area)

-Blind-loop syndrome ; is a condition where food

-bypasses a section of the small intestine, often due to surgery, which can lead to small intestinal bacterial overgrowth => can lead to vomiting , vitamin deficiencies (B12) , diarrhea/steatorrhea , weight loss
-Ileus (paralysis of peristaltic activity within the GI tract) (31)

-Adhesive small bowel obstruction due to scar tissue formation that can even lead to blockage
-Necrotizing Enterocolitis
-Femoral thrombosis due to a central line (in this case)

Note : Generally good prognosis for after surgery but instances have shown late mortality following duodenal atresia repair particularly due to complex cardiac malformations (especially in those patients with Downs syndrome. This is a common issue even in VACTERL. (32)

Associated risk factors: (17, 33, 34)

-Genetic (eg: Downs syndrome, around one third of patients with duodenal atresia have downs syndrome)

-Maternal (eg: Gestational Diabetes, or smoking / drugs or medication like OCP whilst already pregnant) Karyotyping can be useful

-Oesophageal atresia and TEF in 50 - 60 % of cases have been found with the VACTERL association , about 5-10% of patients with duodenal atresia have a VACTERL association. With VACTERL its important to consider other comorbidities as shown in Table 3.

-Syndromes like trisomy 18 and CHARGE syndrome are often linked with mutation in the CHD7 gene and can cause OA/TEF (34)

Presentation of Duodenal Atresia (2 , 4 , 8 , 24 , 35)

Duodenal atresia causes 1 in every 5 - 10 thousand live births.

-Results from failed recanalization during 6th week of gestation ;
https://www.ncbi.nlm.nih.gov/books/NBK537172/

-On antenatal US : Polyhydramniosis (excessive amniotic fluid overload around fetus as fluid cannot enter duodenum to be absorbed in large colon) in around 50 % of cases after 24wks of gestation. ; Double bubble sign due to dilation of the proximal duodenum.

-Postnatal signs ; Vomiting (non bilious or bilious depending on the level of the obstruction in relation to the ampulla of vater i.e. distally (below) results in bilious vomit while proximally (above) results in non bilious).

-Abdominal distention.

-Constipation / absent or trinkling bowel sounds indicative of bowel obstruction.

-Jaundiced

-Blood tests: Electrolyte panel possibly could show dehydration and alkalosis (vomiting) + bilirubin for jaundice.

-Imaging is the primary diagnostic tool using US or echo (associated heart defects), after birth Xray can show the double bubble sign and OGD or GI contrast studies can show the exact location of the atresia.

-Atresia is usually distal (below) the ampulla in 85% of cases , while 15% of cases are usually proximal (above).

Classification of D.A (24 , 35 , 36)

Type 1) Duodenal diaphragm or web , ct

Acronym Component	Anomaly	Atresia/Malformation Type	Frequency
V	Vertebral Defects	Missing, malformed, or fused vertebrae (hemivertebrae, scoliosis, fused ribs).	60–80%
A	Anal Atresia	Also called imperforate anus. The anus opening is missing, blocked, or in the wrong place.	60–90%
C	Cardiac Defects	Structural heart abnormalities, most commonly Ventricular Septal Defect (VSD) and Tetralogy of Fallot.	40–80%
TE	Tracheo-Esophageal	Oesophageal Atresia (EA), often with a Tracheoesophageal Fistula (TEF).	50–80%
R	Renal Anomalies	Kidney defects (single kidney, misplaced or malformed kidneys, hydronephrosis).	50–80%
L	Limb Defects	Abnormalities of the limbs, typically affecting the radial ray (thumb and forearm bones/radius) e.g., missing or underdeveloped thumb.	40–50%

Table 3: VACTERL Summary table (33)

characterized by a thin mucosal membrane that blocks the lumen. The external muscular wall of the duodenum remains intact. This type can occasionally feature a small opening in the membrane , leading to a less severe, intermittent obstruction that may manifest months or potentially years after birth, rather than immediately upon feeding.

Type 2) Fibrous cord , in this complete atresia the proximal and distal ends of the duodenum are separated but remain connected by a short, non patent fibrous cord.

Type 3) Complete separation , involving a complete discontinuity where the duodenal ends have no connecting cord or tissue between them. This is often noted in correlation with annular pancreas (where a ring of pancreatic tissue encircles the descending duodenum, contributing to the obstruction.

Presentation of Oesophageal atresia + Tracheoesophageal fistula (TEF)

-Oesophageal atresia and TEF incidence is estimated as 1 in 3.5 - 5 thousand births (37)

-Arise around the 4th week of gestation caused by defect in lateral septation of the primitive foregut (normally divides the common embryonic

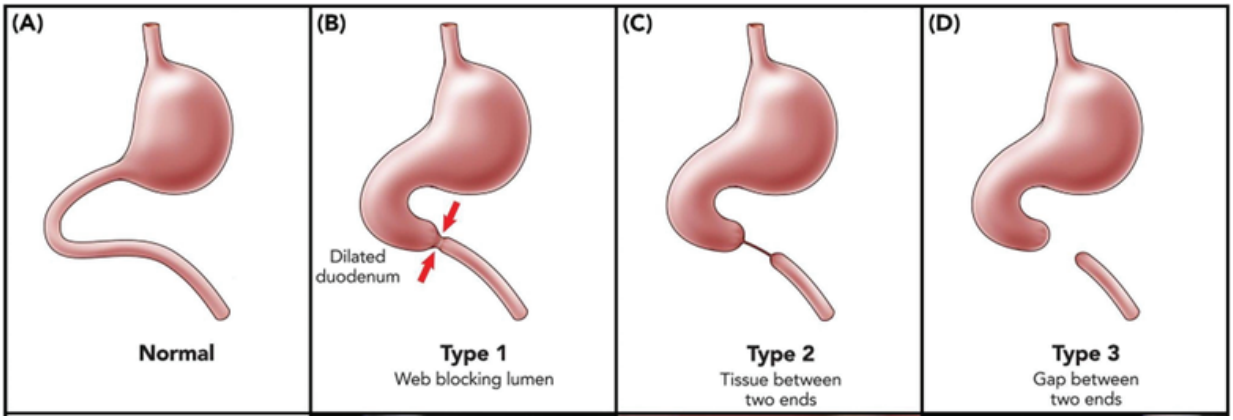

Figure 3: Types of duodenal atresias (36)

precursor into dorsal oesophagus and ventral trachea) (5 , 38)

-Resp distress and choking

-Frequently associated with a tracheo-oesophageal fistula (38)

-Excessive drooling and frothy secretions (as baby cannot swallow saliva or oral secretions because the oesophagus ends in a blind pouch, this leads to pooling of secretions appearing as white frothy bubbles)

-Choking , gagging or coughing when breastfeeding is attempted

-Cyanosis (aspiration into lungs from vomiting)

-Abdominal distention (specifically in the type C classification where a fistula connects the trachea to the distal oesophagus, air from the trachea when the baby cries or breathes is constantly forced through into the stomach)

-In type A cases (long gaps) a staged approach to surgery is preferred over an immediate connection. In complex cases ; delayed primary anastomosis with internal traction, or a jejunal interposition to replace a missing section, may be necessary.

-Postnatal diagnosis is confirmed when a feeding tube (nasogastric catheter) cannot be passed more than 10 to 15 cm from the mouth into the stomach and is visualized coiled in the upper esophageal pouch on chest X-ray. The crucial differentiator between types is the presence or absence of air in the stomach on the X-ray, which confirms communication with the trachea (Types C, D, E) or indicates an isolated atresia (Types A, B) (17, 39)

Very long term outcomes and chronic morbidity:

1. TEF/OA repair (40, 41)

-GERD

-Oesophageal Strictures and dysmotility.

-Tracheomalacia (weakness or structural abnormality in the tracheal wall , this is related to the initial developmental defect involving the shared foregut tissue, prevalence as high as 86.7%
-Chronic pulmonary symptoms (SOB , wheeze , 'honking' cough)

-Recurrent respiratory infections like pneumonia in around 44.2 % of patients often linked to aspirations due to GERD or recurrent TEF.

2. Duodenal atresia repair (40- 42)

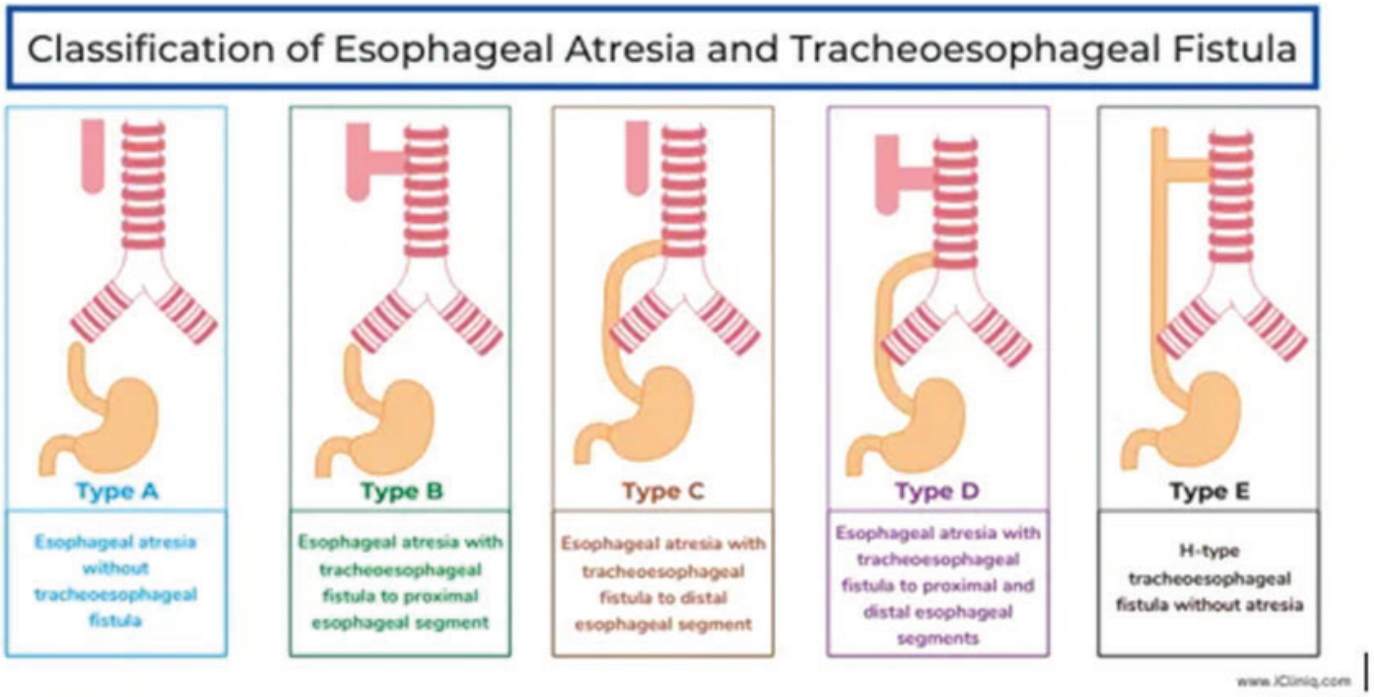

Figure 4: Classification of OA and TEF (44)

Table 3: VACTERL Summary table (33)

Type (Gross/CDC)	Anatomical Configuration	Gastric Air Post-natal	Surgical Complexity	Prevalence
Type A	OA without TEF (Long-gap)	Absent [28]	High (requires delayed/staged repair, Foker process)	Relatively rare (5-10%) 5
Type B	OA with proximal TEF	Absent [28]	High (usually long-gap)	Rare (1-2%) [5]
Type C	OA with distal TEF	Lower esophageal segment to trachea	Present [28]	Most common (80-90%) [5]
Type D	OA with proximal and distal TEF	Both segments connected to trachea	Present	Rare (1%) [5]
Type E (H-Type)	TEF without OA (intact esophagus)	Present	Variable; delayed diagnosis common [5]	Rare (4%)

Classification	Definition	Total	Survival rate
Waterston			
Group A	Birth weight over 2500g and well	42	42/42 (100%)
Group B	Birth weight 1800 g to 2500 g and well or over 2500 g with moderate pneumonia and congenital anomaly	47	43/47 (91.5%)
Group C	Birth weight under1800 g and well or 1800 g to 2500 g with severe pneumonia and severe congenital anomaly	43	21/43 (48.8%)
Spitz			
Group I	Birth weight over 1500 g with no major cardiac anomaly	76	74/76 (97.4%)
Group II	Birth weight less than 1500 g or major cardiac anomaly	45	29/45 (64.4%)
Group III	Birth weight less than 1500 g and major cardiac anomaly	11	3/11 (27.3%)

Figure5 : Spitz classification - prognostic indicator for OA (45)

-Minority suffer from late complications (around 12%)

-Subsequent intervention for adhesive small bowel obstruction, incisional hernia and chronic functional obstruction related to duodenal dysmotility or megaduodenum

-Data from long-term institutional reviews indicate that a significant proportion of DA patients (16% in one series) require additional abdominal operations after initial repair, including procedures such as fundoplication (for GERD, which is also described after DA repair), adhesiolysis, or revision of the original anastomosis, such as tapering duodenoplasty or converting a duodenojejunostomy to a duodenoduodenostomy.

-Late mortality, reported at around 6% in long-term cohorts, is almost entirely attributable to severe associated congenital anomalies, primarily complex cardiac defects and multisystem organ failure.(43)

Case Presentation

The successful management of a neonate presenting with the complex, co-occurring congenital anomalies of Duodenal Atresia and Oesophageal Atresia with Tracheo-oesophageal Fistula relies on rapid diagnosis, prompt surgical intervention, and specialized post-operative care. The distinct embryological origins of DA (failure of recanalization) and OA/TEF (defective septation) necessitate tailored surgical approaches (Kimura anastomosis for DA and primary

repair/anastomosis for OA/TEF).

While immediate surgical success is common, the long-term prognosis is heavily influenced by the presence of associated congenital anomalies, such as cardiac defects linked to Down's syndrome or the VACTERL association. Chronic morbidity following repair, including strictures, GERD, and duodenal dysmotility, remains a significant concern requiring ongoing multidisciplinary follow-up. The case highlights the importance of integrating surgical expertise with meticulous feeding and supportive management (sham feeding, TPN) to optimize both short-term recovery and long-term quality of life for these patients

Acknowledgement

We would like to thank Dr Julie Galea for all her help tutoring us to write this case presentation and with the related literature. (Department of Paediatric Surgery , MDH)

We would like to also thank Dr Elaine Borg for providing us with guidance and opportunity to do this project. (Department Of General Surgery , MDH)

Finally we would like to thank the MMSJ coordinators and MMSA for the opportunity to write and submit this paper, particularly our assigned coordinator , Kimberley Abdilla.

Declarations

We would like to declare we have no conflicts of interest and this paper has been done in view with procedures mostly practised in Malta. May we also declare that no private information regarding the patient this case was based on has been linked or mentioned within this piece.

Authors Contribution

Luke Camilleri and Peter Calleja are in equal parts Dr Julie Galea peer reviewed this piece and tutored us regarding any relevant information we should include or disregard. This would not have been possible without her assistance.

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