especially noticeable in patients whose asthma started after the age of 30. Those most easily weaned were patients whose asthma was seasonal, usually in association with hay-fever, and those whose asthma did not respond. Apart from this, there were 25 periods off treatment lasting more than a year.

Conclusions similar to those of this study are drawn from a review of the literature.

I am indebted to Dr. Howard Nicholson, Dr. Peter Heaf, and Dr. Monica McAllen for permission to study their patients and for a great deal of help, encouragement, and constructive criticism.

REFERENCES

- Arnoldsson, H. (1958). *Acta allerg. (Kbh.)*, **12**, Supp. VI.
 Bickerman, H. A., Barach, A. L., and Itkin, S. (1954). *J. Allergy*, **25**, 312.
 Brockbank, W., Savidge, R. S., and Brebner, H. (1957). *Lancet*, **2**, 666.
 Irwin, J. W., and Burrage, W. S. (1958). *J. Allergy*, **29**, 233.
 Livingstone, J. L. (1958). *Practitioner*, **181**, 693.
 M.R.C. (1956a). *Lancet*, **2**, 798.
 — (1956b). *Ibid.*, **2**, 803.
 Phear, D., Ball, K., and Page, F. (1960). *Ibid.*, **1**, 139.
 Sheldon, J. M., McLean, J. A., and Mathews, K. P. (1955). *J. Mich. med. Soc.*, **54**, 1081.
 Walton, C. H. A. (1956). *Canad. med. Ass. J.*, **75**, 557.
 Williams, D. A. (1959). In *Bronchial Asthma*, p. 52. Chest and Heart Association, London.

MECKEL'S DIVERTICULUM IN CHILDHOOD

BY

R. H. JACKSON, B.M., M.R.C.P.

Consultant Paediatrician, Newcastle upon Tyne and South-East Northumberland Hospital Management Committees

AND

A. R. BIRD, M.B., M.R.C.P.

*General Practitioner, Stockton-on-Tees; lately Registrar, Children's Department, Newcastle General Hospital
 From the Department of Child Health, King's College, Newcastle*

This paper presents a series of 82 children with Meckel's diverticulum. The series was collected in order to obtain facts and figures about the clinical picture of this abnormality in local children to strengthen clinical recognition and provide greater accuracy in teaching. Local studies can also reveal, on occasion, differences of incidence which may suggest the need for a more thorough search for local precipitating factors in the child's environment.

A second reason for studying Meckel's diverticulum in children was the need to estimate its importance as a cause of abdominal pain. One of the most frequent and perplexing problems in paediatrics, both in hospital and in the home, is to know how to manage a child with recurrent abdominal pain, and to decide how far the problem should be investigated. The detailed study of conditions giving rise to abdominal pain is therefore essential if we are to teach students how to manage the everyday illnesses they will frequently meet, and how to recognize early the less common diseases which are potentially serious if delay in diagnosis occurs.

Meckel's diverticulum takes its name from its description in 1809 by Johann Friedrich Meckel, then professor of anatomy at Halle. Diverticula of the intestine had been described before this, but he was the

first person to give a detailed account of the diverticulum and to show that it was a remnant of the vitello-intestinal duct. His evidence for this rested on the following observations: more than one diverticulum with the same structure as the small intestine is never found in the same embryo; the diverticulum is always in the distal part of the small intestine, and it always appears on the antimesenteric border. He also pointed out that the diverticulum is seen in many animal species, but only in those having a yolk sac. He posed a question which he was unable to answer and which remains unanswered to-day—namely, why the duct or some part of it persists (Meckel, 1809; quoted by Söderlund, 1959).

A Meckel's diverticulum consists of remnants of the vitello-intestinal duct, either in whole or in part. If completely patent there will be a vitello-intestinal fistula; a partially patent duct gives rise to a Meckel's diverticulum, an enterocystoma, or a cyst open at the umbilicus, depending upon whether the patent segment is at the inner, middle, or external end of the duct. The only conditions likely to be mistaken anatomically for a Meckel's diverticulum are duplications of the bowel and enterogenous cysts, but a Meckel's diverticulum has its own blood supply and is on the antimesenteric border of the bowel, whereas duplications are intramesenteric and share the same blood supply as the normal bowel.

The incidence of Meckel's diverticulum varies somewhat in different accounts. Harbin (1930) made a systematic search in 500 consecutive laparotomies in infants and children and found a diverticulum in 1.3%, whereas Rosenfeld (1955) found one in 4.5%. Söderlund (1959) looked particularly for a diverticulum in 1954 appendicectomies in Stockholm children and found one in 3.2%.

Meckel's diverticula are said to be commoner in males than in females, and Gross (1953) has a ratio of 3:1 in his series. Söderlund (1959) makes the interesting point that in his series a pathogenic diverticulum—that is, one that is definitely the cause of the patient's symptoms—was five times as common in males as in females, whereas the sex incidence was almost equal in those discovered as an incidental finding. This is borne out in the present series: 49 pathological diverticula occurred in boys and only nine in girls, while silent diverticula were present in 13 boys and 11 girls.

Present Series

The series consists of 82 children from Newcastle upon Tyne and near-by towns who have been found to have a Meckel's diverticulum. They can be classified into three groups (Table I).

TABLE I.—*Clinical Picture in 82 Children with Meckel's Diverticulum*

Group 1: Causing intestinal obstruction	..	..	..	28
By bands, volvulus, etc.	..	..	..	15
By intussusception	..	..	..	13
„ 2: Producing other symptoms	..	..	..	30
Umbilical fistula or sinus	..	..	..	8
Haemorrhage from peptic ulceration	..	..	..	17
Diverticulitis	..	..	..	4
Torsion of diverticulum	..	..	..	1
„ 3: Asymptomatic diverticula	..	..	..	24
Found at laparotomy for intussusception	..	..	..	10
Found at laparotomy for other reasons	..	..	..	14

As Brookes (1954) has pointed out, the complications of Meckel's diverticulum are more likely to occur in young children. In this series 22 children were under 1 year of age and 25 were aged 1, 2, or 3 years. These figures are broadly comparable with other series, though

detailed comparisons are not possible because of the small numbers involved.

There were three deaths in the whole series. Two children died from intestinal obstruction and the third child succumbed to a severe bronchopneumonia which was a sequel to the reduction of an intussusception in a seriously ill patient. In this case the diverticulum was not the cause of the intussusception, and in fact the mortality in pathogenic diverticula is only 2 out of 58, a rate of 3.4%.

Meckel's Diverticulum Causing Intestinal Obstruction

There were 28 children in this group. In 15 the obstruction was due to a band or volvulus associated with the diverticulum, and in 13 the diverticulum was the starting-point of an intussusception. In 10 further children, included in group 3, a Meckel's diverticulum was found associated with but not causing an intussusception.

The histories in the children with intestinal obstruction were straightforward. All except two had obvious abdominal pain; of these two, one was a stoical lad of 11 who was described as having discomfort only, and the other a baby of 5 months who was listless but did not have obvious abdominal colic. All the children vomited, most of them copiously, and all except two were constipated sufficiently for their mothers to remark on it. At least four were given castor oil, and others had syrup of figs, glycerine suppositories, or enemas. In only four children was there any history of previous alimentary upset of any kind; one had had diarrhoea and vomiting on two occasions and infrequent attacks of abdominal pain, one had had an episode of projectile vomiting without pain two years previously, and one had had an attack of right-sided bellyache lasting three days. Only one had had a clear-cut abdominal episode of a serious nature, and she was a girl of 11 who had undergone appendicectomy. This comparative absence of previous abdominal pain contrasts with the series of Söderlund (1959), in which 50% of the cases had had previous abdominal symptoms.

In most children the duration of symptoms was short, and 11 of the 15 were in hospital within 48 hours. The classical signs of acute obstruction were present in the majority on admission, so that operation was carried out shortly after in all except four children. Two—one in 1946 and the other in 1951—were so desperately ill that in spite of resuscitation they died shortly after arriving in hospital, before they could be operated on. These account for two of the three deaths in the series. In two other cases diagnosis was difficult: one developed diarrhoea after admission, having previously been constipated, and the other had normal bowel actions before admission. This boy had infrequent abdominal colic for six days after admission, until, after a sudden exacerbation, a mass was found. Operation revealed a long Meckel's diverticulum with the tip adherent to the posterior abdominal wall and the bowel twisted round it.

The group causing obstruction by intussusception was also straightforward. Harkins (1933) stated that there were several distinguishing features about intussusception due to Meckel's diverticulum. He felt that it occurred more commonly in older children, that previous attacks were more frequent, vomiting more intense, and the course of the illness more chronic. Our

experience tends to support an older age of onset, as only one child was under a year, one was under 2 years, and five were over 5 years. Previous attacks were not very striking, however, as only three of our children had histories which in any way resembled an intussusception. One child was admitted to hospital three times: the first time it was thought an intussusception had reduced spontaneously, on his second admission a laparotomy was performed and an intussusception reduced, and on his third three intussusceptions were found and at the apex of the highest was an invaginated Meckel's diverticulum.

As regards chronicity of illness 5 of our 13 children were in hospital within 24 hours and another five within 48 hours. The longest history was four days. All recovered, though many were seriously ill on admission and five (38%) needed a resection; this is a very high proportion compared with the 5% of 424 intussusceptions analysed by Court and Jones (1955). One child emphasizes an important point in management; she was admitted at the age of 2 with an intussusception starting with an invaginated Meckel's diverticulum, which was not removed at the time. The surgeon concerned advised removal at a later date, but, unfortunately, this was not done until eight years later, when she was readmitted with subacute intestinal obstruction.

Meckel's Diverticulum with Non-obstructive Symptoms

Umbilical Fistula or Sinus

There were eight children with either complete or partial patency of the vitello-intestinal duct, presenting as an umbilical fistula or sinus. A complete fistula with faeces coming from the umbilicus is rare, and only 180 cases have been reported in the literature (Söderlund, 1959). There were three such cases in this series. The first child, who was 18 months old at the time of operation, had had since birth a continuous discharge from the umbilicus which shortly before his admission became copious and offensive and eventually faeculent. Barium given by mouth appeared at the umbilicus half an hour later. If the duct is partially patent there is clear or mucoid discharge from the umbilicus, sometimes with occasional bleeding. There may be a prolapse of the intestine into the centre of an abnormally thick umbilical cord, which in some cases is so large and wide as to mimic an exomphalos. This applied to two children in this series: in one the cord was $\frac{3}{4}$ in. (2 cm.) thick and the bowel was protruding some 2 in. (5 cm.) into it. One baby had a partially patent duct together with a talc granuloma, both being proved histologically, with the sinus showing a transition from normal skin to an intestinal type of mucosa. In one other child there was marked digestion of the skin round the umbilicus, by the discharge.

Peptic Ulceration and Haemorrhage

Seventeen children presented with peptic ulceration and haemorrhage, and in three the ulcer perforated and produced a peritonitis. One of these was the only girl in the group, and she had a history of abdominal pain and vomiting for the 16 hours at the age of 18 months. She had a generalized peritonitis on admission, but rectal examination produced a somewhat abnormal stool which had a positive occult-blood reaction. The diagnosis of a generalized peritonitis secondary to a perforated

Meckel's diverticulum was made, being confirmed at laparotomy.

Six children presented with acute gastro-intestinal haemorrhage which warranted an emergency operation without further investigation. Five were babies under 1 year of age, and in three the pre-operative diagnosis was of bleeding from a Meckel's diverticulum rather than an intussusception; in one the diagnosis was made because of a past history of two attacks of rectal bleeding, and in the other two because the amount of blood seemed out of proportion to the pain. The remaining eight children in this group presented with bleeding into the alimentary tract which, although acute in some cases, nevertheless did not cause enough anxiety to warrant operation as an emergency, and in which, therefore, investigations were possible before operation. All except one were over 1 year old; this infant and one older child were the only children with a history of melaena before the current episode which brought them to hospital.

The histories of the 14 children with unperforated peptic ulcers were fairly consistent. With one exception symptoms had been present for one or two days only. Haemorrhage occurred in all of them. Pain was also present in all, though it varied from severe colic to apparently mild discomfort. There was no obvious relationship of pain to meals. The general difficulty of recognizing pain in a small baby may arise here as it does also in intussusception. There may be a past history of pain with melaena, but only one child in this whole group of 17 cases had a history of pain without bleeding. He was the one child whose symptoms had lasted for more than 48 hours, but they consisted of epigastric pain lasting a few days only, three weeks before admission. Pallor was noticed in most of the children, but vomiting was not a prominent symptom and occurred in only four. The colour of the stools varied from frank red blood with clots to very dark stools like melaena, but most were the classical dark-red colour.

Meckel's Diverticulitis

The clinical picture of diverticulitis as shown in the four children in this series is indistinguishable from acute appendicitis. It has been said that the pain of an inflamed Meckel's diverticulum is more "wandering" than that of appendicitis, but this was not obvious in this small group. In none of the children had there been any previous abdominal pain or intestinal bleeding. The appendix was normal in all cases, and the diverticulum grossly inflamed and oedematous with some peritoneal exudate. In one child there was frank pus about the diverticulum, with a definite perforation: histology showed acute inflammatory ulceration and perforation without peptic ulceration. A foreign body, probably a piece of apple core, was also present in the diverticulum. Occasionally calculi or concretions are found, but there were none in this series.

Torsion of Diverticulum

The last child in whom a diverticulum gave rise to symptoms was a boy of 3 in whom a torsion occurred. He had a three-day history of pain, and on examination a tender mass was found in the right iliac fossa. At operation a large Meckel's diverticulum had twisted on itself, producing an almost gangrenous mass about 2 in. (5 cm.) in diameter. Similar cases have been reported before (Gross, 1953), but they are exceedingly rare.

Asymptomatic Diverticulum as an Incidental Finding

This group consists of 24 children in whom a Meckel's diverticulum was an incidental finding and not apparently responsible for the symptoms of which the child was complaining. Obviously there will have been other children operated on during the years under review who had Meckel's diverticula that were not seen at operation or not recorded in the notes, and therefore it is not possible to give any figure for the total incidence of the abnormality.

The most interesting feature is that in no fewer than 10 of these 24 children the diverticulum was found during a laparotomy for the reduction of an intussusception, but could not be incriminated as its cause. At first sight this suggests an association between Meckel's diverticulum and the production of an intussusception, but there is no particular reference to this in the literature. Söderlund (1959) mentions 222 diverticula found incidentally, but makes no mention of intussusception among the indications for the laparotomy. A more reasonable explanation for this apparent association—though it does not explain the absence of a similar finding by others—is that the ileocaecal region is more likely to be thoroughly inspected by the surgeon during the reduction of an intussusception than during a laparotomy for other reasons; these findings may therefore reflect more nearly the true incidence of Meckel's diverticulum. That this is so is shown by the fact that in 924 consecutive cases of intussusception at the two main hospitals in Newcastle upon Tyne, 20 Meckel's diverticula were found either as the cause or incidentally. This gives an incidence of 2.1%, which is of the same order as published figures for the total incidence. It does not seem, therefore, as if children who have a Meckel's diverticulum are much more likely to develop an intussusception: they are merely more likely to have it discovered if they get one.

The indications for laparotomy or the findings at operation in the other 14 children were: four cases of acute appendicitis, five of acute abdominal emergencies other than appendicitis, and one case of congenital pyloric stenosis. There were also four children who had exploratory operations for recurrent abdominal pain. In none of these, however, could the Meckel's diverticulum be blamed for the pain; in three of them histological examination revealed no evidence of inflammatory ulceration or mucosal heterotopia in the diverticulum. In the fourth child, a girl, symptoms persisted after the diverticulum had been removed.

The main question posed by the last four children is whether a Meckel's diverticulum can ever give rise to recurrent attacks of abdominal pain without other symptoms. Recurrent abdominal pain is one of the commonest and most difficult problems that family doctors, surgeons, and paediatricians are faced with, and opinions vary concerning the frequency with which a diverticulum is the cause. Söderlund (1959) feels that symptoms are unlikely to arise from a Meckel's diverticulum in which there is neither inflammation nor gastric or pancreatic heterotopia, but he is not prepared to say categorically that they never do. So often the problem is bedevilled by the fact that a normal appendix is removed at the same time as the diverticulum, so that one cannot say which, if either, was the cause of the trouble. One has to take into account the natural history of recurrent abdominal pain in children, which usually proceeds to a spontaneous cure. In addition,

as Apley (1959) stresses, quite a large proportion of such pains are entirely psychological in origin or have a very large psychological element in them. In this series, at any rate, it is clear that sooner or later—and usually sooner—a Meckel's diverticulum which is going to cause trouble will do so in an unmistakable fashion by causing an acute episode which demands a laparotomy or by producing definite symptoms which warrant investigation. To do a laparotomy on the chance of finding a Meckel's diverticulum to account for recurrent abdominal pain does not seem justified.

Another problem which confronts a surgeon is to know what to do with a normal-looking diverticulum found during the course of a laparotomy. On the balance of evidence removal appears to be a safe procedure, but obviously each case must be assessed on its merits, taking into account the size and shape of the diverticulum and whether resection of gut is necessary in order to remove it. One point in favour of removing such a diverticulum is that there are on record cases, such as the one described earlier, in which a second laparotomy was necessary to remove a pathological diverticulum which had not been giving rise to symptoms at the time of the first operation.

Pathological Changes

Histopathological studies were not carried out on all cases in this series, and therefore no useful comments can be made concerning the frequency of the different types of change. Such studies are useful, however, in confirming the presence of gastric or pancreatic heterotopia and of peptic ulceration, in proving the diagnosis of diverticulitis, and also in proving that an umbilical sinus is lined by intestinal mucosa. Examples of all these changes were, of course, seen in this series.

Comparisons with Other Published Series

Comparison of one series with another is made difficult by differences in terminology. In some series cases are classified as diverticulitis when there is no evidence of inflammation, and in others the authors have a special category for perforations irrespective of whether these are the result of peptic ulceration or of diverticulitis. In Table II a comparison is drawn between this series and four others from different parts of the world.

TABLE II.—Comparison of Pathological Changes Associated with Meckel's Diverticulum (Figures Given as Percentage of Total Number of Pathological Diverticula)

	Söderlund (1959)	Gross (1953)	Wansbrough <i>et al.</i> (1957)	Aitken (1953)	Present Series
Intestinal obstruction:					
bands, etc.	24	7	25	24	26
Intussusception	17	23	25	11	23
Peptic ulceration	33	43	20	16	29
Diverticulitis	12	14	5	35	7
Umbilical fistula or sinus . .	13	9	11	8	15
Other	1	3	14	5	1

In comparison with Söderlund's findings in Sweden, Newcastle shows a lower incidence of diverticulitis and peptic ulceration. Gross has a high percentage of ulceration and haemorrhage (43%) and a low figure for obstruction, but a clear distinction is not drawn between cases in which the diverticulum caused the intussusception and those in which it was merely present. The

low incidence of diverticulitis in the children of Wansbrough *et al.* may be explained by the fact that they have a special category for perforations. The children described by Aitken in Glasgow had a high incidence of diverticulitis, but he includes some in whom an apparently normal diverticulum was removed for recurrent abdominal pain. One possible explanation for the low incidence of diverticulitis in Newcastle is that cases were included under this heading only when a gross abnormality was present, leading in all cases to emergency admission and operation. It has been our policy in recent years to try to reach a definite diagnosis before submitting a child to a laparotomy. We have tried, so far as is reasonably possible, to resist the temptation to look and see in cases of mild abdominal pain with indefinite physical signs, and this policy may have led to some mild cases of diverticulitis being missed because the child was not operated on.

Summary

The clinical picture and operative findings in 82 children with Meckel's diverticulum are presented.

The clinical picture was almost invariably an acute one and seldom if ever gave rise to recurrent abdominal pain without other symptoms. Laparotomy in children with recurrent abdominal pains unassociated with haemorrhage or obstruction in the hope of finding a Meckel's diverticulum does not seem justified.

In comparison with other accounts of this malformation more children presented with intestinal obstruction and fewer with diverticulitis.

We are grateful to all our surgical colleagues, especially to Mr. S. Fegetter, Mr. D. Hindmarsh, and Mr. J. D. T. Jones, who have operated on these children. Our thanks are also due to Professor S. D. M. Court and Drs. Christine Cooper, G. Davison, and F. J. W. Miller, under whose care they have been admitted. Dr. J. Hart Mercer kindly examined many pathological specimens at our request. We are especially grateful to Professor Court, who initially suggested this study, for his advice and helpful criticism.

REFERENCES

- Aitken, J. (1953). *Arch. Dis. Childh.*, **28**, 1.
 Apley, J. (1959). *The Child with Abdominal Pains*. Blackwell, Oxford.
 Brookes, V. S. (1954). *Brit. J. Surg.*, **42**, 57.
 Court, S. D. M., and Jones, J. D. T. (1955). *Med. Ill. (Lond.)*, **9**, 63.
 Gross, R. E. (1953). *The Surgery of Infancy and Childhood*. Saunders, Philadelphia and London.
 Harbin, R. M. (1930). *Surg. Gynec. Obstet.*, **51**, 863.
 Harkins, H. N. (1933). *Ann. Surg.*, **98**, 1070.
 Meckel, J. F. (1809). *Pflügers Arch. ges. Physiol.*, **9**, 421.
 Rosenfeld, W. (1955). *Zbl. Chir.*, **80**, 2024.
 Söderlund, S. (1959). *Acta chir. scand.*, Suppl. 248.
 Wansbrough, R. M., Thomson, S., and Leckey, R. G. (1957). *Canad. J. Surg.*, **1**, 15.

At the Clean Air Conference held in Brighton Lord COHEN OF BIRKENHEAD stressed the importance of prospective studies on the relation of air pollution to disease. "We can," he said, "watch with care the effects of the Clean Air Act, of removing smoke and offending pollutants from the atmosphere of our cities. If what we believe is valid, then we can expect in smokeless zones a reduction in the incidence of chronic bronchitis, bronchial cancer, and other diseases in which air pollution is a contributory cause, provided, and it is an important reservation, that two other highly relevant factors—namely, cigarette smoking and automobile exhaust gases—do not gain so much in strength that they offset the benefit of air cleansed from other pollutants."