Formation of an Artificial Vagina Using Intestine

Robert Anthony MacMahon

University of Colorado Boulder

Follow this and additional works at: https://scholar.colorado.edu/print_theses

Recommended Citation


https://scholar.colorado.edu/print_theses/183

This Dissertation is brought to you for free and open access by University Libraries at CU Scholar. It has been accepted for inclusion in University Libraries Digitized Theses 189x-20xx by an authorized administrator of CU Scholar. For more information, please contact cuscholaradmin@colorado.edu.
FORMATION OF AN ARTIFICIAL VAGINA USING INTESTINE

Robert Anthony MacMahon
MB, B.S., Sydney University, 1954
F.R.C.S., Edinburgh, 1960

by

Robert Anthony MacMahon

MB, B.S., Sydney University, 1954
F.R.C.S., Edinburgh, 1960

A thesis submitted to the Faculty of the Graduate School of the University of Colorado in partial fulfillment of the requirements for the Degree Master of Science

Department of Surgery

1965
This Thesis for the M.S. degree by

Robert Anthony MacMahon

has been approved for the

Department of

Surgery

by

__________________________
Bruce C. Paton

__________________________
William R. Waddell

Date 22nd October 1964
MacMahon, Robert Anthony (M.S., Surgery)

Formation of an Artificial Vagina Using Intestine

Thesis directed by Assistant Professor Bruce C. Paton

Certain patients with congenital absence of the vagina would be greatly benefitted by an operation to correct this defect about the time of puberty. The usual operation, placing split-thickness skin grafts on a molded obturator in a preformed space for 3 to 6 months, with subsequent dilatation as necessary, is not suitable for this procedure.

The use of a loop of intestine might be the procedure of choice if the problems of the previous mortality and morbidity with this method could be overcome. This procedure would also provide a connection between a possible functioning uterus and the exterior. Twenty-nine dogs and one sheep were operated on to investigate the potential of the method with modern surgical techniques and pre- and post-operative care; and also to test the effects of such an operation on fertility. There was no mortality or appreciable morbidity from the intestinal stage of the operation. However, in dogs it was found that perforation of the ileal loop occurred during copulation because of the small lumen and relatively weak wall.

The results of this experiment and the experiences of
of others indicate that the use of an intestinal loop is a safe operative procedure; that sigmoid colon is preferable to ileum; but that, if ileum is used, a doubled loop with entero-enterostomy to form a wide lumen is a safe alternative procedure.

This abstract of about 221 words is approved as to form and content. I recommend its publication.

Signed
Instructor in charge of dissertation
TABLE OF CONTENTS

Introduction---------------------------------------1
Embryology----------------------------------------4
Clinical Features----------------------------------9
Purpose of the Experiment------------------------14
Experimental Procedure--------------------------16
Results------------------------------------------29
Review of the Literature------------------------33
Discussion----------------------------------------46
Summary------------------------------------------52
References----------------------------------------53
INTRODUCTION

Vaginal replacement is needed in two groups of patients --those in whom atresia or aplasia of the vagina occurs as a simple embryological defect, and those in whom vaginal replacement is required because of a major disturbance of sexual development in the intersex syndromes.

(a) Historical aspects and incidence.

Congenital absence of the vagina as a simple embryological defect is a rare condition. Engstad reports it as occurring once in 5,000 births, Owens found only six cases in 125,000 female hospital admissions, while Bryan, Nigro and Counseller found its incidence to be one per 4,000 female patients. As Counseller has a world wide reputation for operations on this abnormality, this last figure is abnormally high.

According to Steinmetz, this condition was first described by Realdus Columbus in 1572 but the first attempt at surgical correction was not performed till 1817 by Dupuytren. Heppner in 1872 was the first to use free skin grafts and Sneguireff in 1892 utilized a portion of the rectum. From this time on, numerous methods of correction were tried with variable but increasing success.

The historical records of the Intersex states go back to
ancient times. Hermaphrodites, symbolic of half man, half woman was considered one of the minor Greek divinities, but the latter day Greeks viewed them with scorn and derision and cast them into the sea. Legend has it that a cock was sentenced and burned at the stake in Basle in 1474 for the heinous and unnatural crime of laying an egg.

The first major advance in the differentiation of the Intersex states was made in 1866 when Creechio described the syndrome of female pseudohermaphroditism in association with enlargement of the cortex of the suprarenal gland without other evidence of adrenal dysfunction. This group of virilisation due to adrenal hyperplasia constitutes the commonest type of intersex (34.7% of a personal survey) with an incidence of about one in 67,000.

The incidence of the other types of hermaphroditism is not known but they are certainly less common than adrenal hyperplasia.

The development of methods of replacement of the vagina preceded the differentiation of the various states in which abnormalities of the vagina occur, so that the methods have been developed and used regardless of the etiology.

(b) Outline of thesis.

The problem under consideration is the place of intest-
nal loop vaginal reconstruction in the types of patient mentioned above. The factors involved can be better understood by a consideration of the etiology and type of defect from the embryologic viewpoint and of the clinical features of the type of patient involved. Thus the development of the genital system is briefly described, followed by a description of the relevant clinical features and a classification of the Intersex syndromes to illustrate the categories in which vaginal reconstruction may be needed.

Finally the method used, and the results obtained, in these experiments in animals, of replacing the vagina with a loop of intestine, are reported and discussed in relation to other methods of vaginal reconstruction.
EMBRYOLOGY

One of the striking aspects of the development of the reproductive system is the condition which at first exists regarding sexual differentiation. One might expect that reproductive mechanisms as unlike as those of adult males and females would be sharply differentiated from one another from their earliest appearance, but this is not the case. Young embryos exhibit gonads which at first give no evidence whether they are destined to develop into testes or ovaries. Along with these neuter or indifferent gonads there is present a double set of sexual duct systems.

It is postulated that the physiologic reactions controlled by the unequal balance of the sex-determining genes effects the differentiation of the bipotential gonad as either testis or ovary. Spontaneous and experimentally produced forms of ambisexual development attest that this genetic balance system is not absolute and may be modified by various genetic, hormonal, and environmental factors.

Sex differentiation takes place in three steps involving successively (a) the gonad, (b) the genital ducts and (c) the urogenital sinus and the external genitalia. Normally the pattern of all the sexual structures conform, as their differentiation progresses, to the genetic sex established in the
zygote at the moment of fertilization.

Whereas the primordial gonad is bipotential, each somatic element is unipotential: the cortical component can differentiate only as an ovary and the medullar only as a testis. During differentiation, each of these elements competes for dominance, the dominant element conforms to the genetic sex of the zygote and the recessive element retrogresses. Hence, gonadal sex is established by the outcome of this competitive relationship.

The study of the bovine freemartin has made an important contribution to the concept of gonadogenesis in placental mammals. In this freemartin an ovary has been transformed into an immature testis, not only by an embryonic morphogenetic substance transmitted through the circulation from the male twin, but in opposition to the genetic constitution of the fetus. The nature of this presumably hormonal sex-differentiating substance or inductor is unknown.

The second and third stages of sex differentiation involve the somatic sex organs. These structures can be divided into two groups according to their differentiation from distinct primordia--the Mullerian and Wolffian ducts--or from bisexual primordia--the urogenital sinus and the genital tubercle--which have the capacity to develop along masculine
or feminine lines.

In the embryo during the indifferent stage, Mullerian ducts, or oviducts, and the Wolffian ducts, or mesonephric ducts, exist as a paired set of structures. The Mullerian ducts first appear in the latter part of the second month close beside the mesonephric ducts, whereas the male ducts are not developed primarily as reproductive ducts, but are appropriated from the regressing mesonephros, some of the mesonephric tubules becoming connected with the developing gonad and the mesonephric duct being used as a discharge passage for the sex cells.

If the embryo is developing into a female the Wolffian ducts regress while the Mullerian ducts develop to form the uterine tubes, uterus and vagina. Where the fused distal ends of the Mullerian ducts make contact with the urogenital sinus, their potential lumen is packed solidly with epithelial cells of the type which line the lumen higher up where it is not occluded. Meeting and merging with this cord of Mullerian duct cells are cells growing back from the epithelial lining of the urogenital sinus. The projection of this combined cell mass into the lumen of the urogenital sinus is known as the Mullerian tubercle. It is conspicuous in the early stages of development before the solid cell mass of
which it is composed opens up to connect the lumen of the upper part of the vagina with the urogenital sinus. Where this tubercle later opens up to establish the vaginal orifice is clearly marked by the hymen. In the formation of the distal portion of the vaginal lumen there seems to be a tendency for the epithelial cells of urogenital sinus origin to proliferate very rapidly and to push in, replacing the epithelial cells in the lower part of the fused Mullerian ducts. How far this proceeds is still a matter of controversy.

In man, the Mullerian ducts are fused with each other to form a simplex type of uterus, but although it is established early, the uterus attains its characteristic configuration only gradually.

According to the studies of Jost in the rabbit and of Raynaud and Frilley in the mouse, removal or ablation of the fetal ovary did not hinder differentiation of a female genital system. However, absence of the fetal testis and its morphogenetic hormone during an early critical period prevented the differentiation of male structures and resulted in entirely female development of the ducts, urogenital sinus, and external genitalia. It is thus evident that a fetal testicular morphogenetic substance is essential for differentiation of male sex structures, for retrogression of the
female ducts, and to prevent the inherent tendency of the fetus to feminize.

Jost further demonstrated that postponement of castration of the fetal testis to progressively later stages resulted in a more masculine-appearing genital tract, until finally castration of male fetuses no longer prevented male sex differentiation.

Our knowledge of other factors capable of modifying the development of the accessory sex structures is meager. For example, the mesonephric duct has an important, although poorly understood, effect on the early development of the Mullerian duct, accounting for the common association of internal genital and renal abnormalities.

The more common abnormalities of the uterus and vagina are the result of variations in the extent or manner of fusion and recannalisation of the Mullerian ducts during their early development. There may be a failure of the cervical portion of the uterus to develop so that a slender strand of tissue, completely without a lumen, is all that connects the fundus of the uterus with the vagina. Local atrophy may affect the vagina as well as the uterus, or the lower part of the vagina may fail to acquire a lumen and remain as a solid cord.
Those patients in whom atresia or aplasia of the vagina occurs as a simple embryological defect are usually in all other respects normal females. The ovaries are invariably present and function normally as indicated by the development of normal female secondary sex characteristics. The external genitalia, pubic hair and breasts develop normally and the body contour and mental attitudes are entirely feminine. The abnormality is usually discovered (90%\textsuperscript{7}) on examination because of amenorrhea but occasionally manifests itself because of the symptoms and signs of haematometra and haematosalpinx shortly after puberty, or because of inability to have intercourse (10%\textsuperscript{7}).

The physical findings are those of a normal female on external examination but the vagina is represented usually by a shallow vaginal vestibule only, extending inwards one to three cm. Rarely, other types of vaginal abnormalities may be present, such as limited atresias, fistulous tracts or septate vaginas. This abnormality is usually associated with absent uterus and tubes but Bryan, Nigro and Counseller\textsuperscript{7} found 20 patients with apparently functional uteri in 100 cases; McIndoe\textsuperscript{33} found six patients out of 93 (6.4%); while Thompson, Wharton and TeLinde\textsuperscript{45} found two out of 32 with a
functional uterus present (6.3%).

Associated anomalies of the upper urinary tract are also common and this association is easily understandable on the basis of the embryological development of the genito-urinary system, previously described. In the series of 100 patients reported by Bryan, et al, 41 underwent a urologic investigation. Twenty-one patients were found to have abnormalities of the urinary tract of whom seven had pelvic kidneys, five had solitary kidneys, four had a duplicated ureter or renal pelvis, two had pyelo-ureterectasis, one had a malfunctioning kidney, one had a solitary fused kidney and one had had nephrectomy on the right for unstated reasons. Ten patients had abnormalities on the right side, and 11 patients had abnormalities on the left side.

The clinical features of the intersex syndromes are basically ambiguous external genitalia, which may be predominantly male, predominantly female or an indistinguishable mixture associated with various degrees of persistence of derivatives of both Mullerian and Wolffian duct structures. Various classifications of the intersex syndromes have been proposed from time to time, but the most basic and most commonly used is that which divides these patients into three
groups, male pseudohermaphrodites, female pseudohermaphrodites, and true hermaphrodites. The males have only testicular tissue on bilateral gonad biopsy, the females only ovarian tissue and the true hermaphrodites both ovarian and testicular tissues. Various other syndromes such as Turner's and Klinefelter's are often included in the group of intersex syndromes, but they do not present surgical problems and are not included here.

A clinical classification is illustrated by Table I, a group of intersex syndrome patients from a personal survey conducted over a ten-year period at a children's hospital.

The female pseudohermaphrodites usually have only minor abnormalities of the vagina, and vaginal replacement is not necessary. However, construction of a vagina is necessary in some cases of testicular feminization, in male pseudohermaphrodites with inadequate genitalia who are reared as females, and in true hermaphrodites without a vagina who are reared as females.

Because of the unsatisfactory nature of previous methods of early vaginal replacement, and because of the psychological and social problems with both patient and family, particularly if a change of sex is involved, frequently the appro-
appropriate decision to rear such patients as female has not been taken. This type of case is well illustrated by the true hermaphrodites in the series in Table I, all of whom are being reared as males, and one of whom had a right ovary, a left ovo-testis, a normal appearing uterus and tubes, the uterus opening into a short blind vaginal pouch, and who had a normal female karyotype on leucocyte culture. Excision of the left ovo-testis and a somewhat enlarged phallus, and construction of a vagina would have left an anatomical and chromosomal female with an interesting theoretical possibility of fertility.

<table>
<thead>
<tr>
<th>Male pseudohermaphrodites</th>
<th>27</th>
<th>37.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Hypospadias and undescended testes</td>
<td>12</td>
<td>16.7</td>
</tr>
<tr>
<td>(2) Testicular feminization</td>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>(3) Inadequate male genitalia</td>
<td>12</td>
<td>16.7</td>
</tr>
</tbody>
</table>

True hermaphrodites | 6 | 8.3 |

* Excluding those with Turner's and Klinefelter's syndromes.
<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of hermaphrodites</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>Female pseudohermaphrodites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Adrenal hyperplasia</td>
<td>25</td>
<td>34.7</td>
</tr>
<tr>
<td>(2) Hormones in pregnancy</td>
<td>8</td>
<td>11.1</td>
</tr>
<tr>
<td>(3) No obvious cause</td>
<td>6</td>
<td>8.4</td>
</tr>
<tr>
<td>Male pseudohermaphrodites</td>
<td>27</td>
<td>37.5</td>
</tr>
<tr>
<td>(1) Hypospadias and undescended testes</td>
<td>12</td>
<td>16.7</td>
</tr>
<tr>
<td>(2) Testicular feminization</td>
<td>3</td>
<td>4.1</td>
</tr>
<tr>
<td>(3) Inadequate male genitalia</td>
<td>12</td>
<td>16.7</td>
</tr>
<tr>
<td>True hermaphrodites</td>
<td>6</td>
<td>8.3</td>
</tr>
</tbody>
</table>

* Excluding those with Turner's and Klinefelter's syndromes.
PURPOSE OF THE EXPERIMENT

The ideal operation for any type of vaginal atresia or aplasia would be one that allowed adequate sexual function, that would connect any functioning internal genital organs to the exterior, that had no mortality or morbidity, that could be applied early in life and would not need any elaborate post-operative care and would still allow good function years later.

The points of being applicable early in life, needing a minimum of post-operative care and being functional years later apply particularly to those cases where psychological factors are involved, such as in the intersex syndromes and some patients with vaginal aplasia. These two points also apply particularly to those patients presenting soon after puberty with haematometra.

The commonest method of vaginal repair using split thickness skin grafts has the disadvantage of needing continuous dilatation for 3 to 6 months and there is still a tendency for contracture of the cavity unless the patient marries or intermittent dilatation is performed.

Though intestine for vaginal replacement was first used in 1892, because of the mortality and morbidity the method fell into disrepute.
The purpose of the present study was to ascertain on experimental animals, using the modern methods of intestinal surgery, the mortality and morbidity of the intestinal replacement method, and the feasibility of regularly anastomosing a functioning uterus to a loop of intestine, and its effect on fertility.

However, a loop of ileum could be raised with adequate arterial and venous drainage and brought to the exterior via the vaginal canal.

A further complicating factor in the dog and most animals was that the urethra opens into the anterior aspect of the lower end of the vagina, so that an anastomosis could not be made between the loop and skin of the vaginal introitus without some type of urinary diversion.

It was decided in the first instance to operate on a series of dogs, excising the vagina and replacing it with a loop of ileum, the upper anastomosis being made to a short cuff of vagina at the cervix and the lower anastomosis to the lower segment of vagina just above the entry of the urethra. An initial group of those dogs would be sacrificed at monthly intervals to see the state of the ileal loop and
EXPERIMENTAL PROCEDURE

Several dogs were dissected postmortem to determine the feasibility of the use of a loop of intestine after excision of the vagina. It was found that the venous drainage of the rectum and sigmoid in the dog ran by a large marginal vessel and there was no separate trunk passing medially on which an isolated loop could be raised. However, a loop of ileum could be raised with adequate arterial and venous drainage and brought to the exterior via the vaginal canal.

A further complicating factor in the dog and most animals was that the urethra opens into the anterior aspect of the lower end of the vagina, so that an anastomosis could not be made between the loop and skin of the vaginal introitus without some type of urinary diversion.

It was decided in the first instance to operate on a series of dogs, excising the vagina and replacing it with a loop of ileum, the upper anastomosis being made to a short cuff of vagina at the cervix and the lower anastomosis to the lower segment of vagina just above the entry of the urethra. An initial group of these dogs would be sacrificed at monthly intervals to see the state of the ileal loop and
anastomoses while the rest would be mated with a male to test the possibility of copulation, fertility and parturition.

**Method:**

Pre-operation medication: Sulfathalidine 0.1-0.5 gm/kg body weight/day for three days.

Urecholine, 5 mg. the day before operation.

Sulfathalidine was used in the preparation of the intestine because it is only slightly absorbed, is relatively non-toxic, and results in a high concentration of the drug in the contents of the intestinal tract where it exerts bacteriostatic action.

Urecholine (bethanechol) is the urethane of B-methylcholine, stimulating the musculature of the gastrointestinal tract and urinary bladder and effects emptying of the bladder and colon.

**Technique:**

Anaesthesia was induced by intravenous nembutal in a dose of 30 mg/kg. A cuffed endotracheal tube was inserted and connected to an automatic respirator delivering oxygen.

An intravenous cannula was inserted into a foreleg vein to deliver fluid and blood as necessary and a No. 12 Foley catheter was inserted into the bladder.
A lower midline, abdominal incision was made and the peritoneal cavity opened. In the first animal, the incision was extended down over the symphysis pubis and the pubis divided. However, there was a good deal of bleeding from the divided bone and reasonable separation could not be obtained. Approximation was also difficult so this was not done in future operations. The vagina was then dissected and isolated, ligating and dividing the vascular leashes from the cervix to the entry of the urethra.

A loop of lower ileum was then raised on a vascular pedicle. Care was taken to see that the feeding artery and draining vein were attached to the loop within an inch of the upper end and that the marginal artery and vein were of reasonable calibre throughout the length of the segment of the ileum. In one animal in which the artery was of very small size the tension applied in placing it in the position of the vagina was enough to devascularize the loop. The loop and the vascular leash were then passed behind one of the uterine horns if possible, but if not, passed anterior to one horn.

The continuity of the ileum was restored by an end to end anastomosis using a continuous 00 chromic catgut, all-layers inverting suture. Additional interrupted sutures of the same
material were placed as necessary to obtain serosa to serosa opposition throughout the circumference of the suture line. The opening in the mesentery was closed with interrupted catgut sutures.

The vagina was then divided just below the cervix and the upper vaginal cuff was incised for one cm. longitudinally, anteriorly to enlarge the anastomosis. The proximal end of the ileal loop was then anastomosed to this upper vaginal cuff by interrupted 000 inverting black silk sutures.

The lower anastomosis was a more difficult problem. Because of the broad symphysis pubis of the dog, and the fact that the urethra enters the vagina deep in the pelvis behind this broad symphysis, it was not practical to attempt the lower anastomosis from above. Accordingly, the lower segment of the vagina was turned inside out, the proximal end being drawn through the vaginal introitus.

The lower end of the ileal loop had been closed by a continuous inverting black silk suture immediately after its isolation, and the ends of the suture left long. A Kelly's forcep was now inserted up the inside-out vagina, the long ends of the inverting suture grasped and the lower end of the ileal loop pulled through. Usually a longer loop than was
necessary to replace the vaginal segment was isolated so that the lower end of the ileum could be drawn well out to the exterior.

Traction was then exerted on the vagina and on the drawn-through loop of ileum. An anterior transverse incision was then made, as far superiorly as possible through the vagina and then the anterior wall of the ileal loop. Anastomosis was then commenced with interrupted 00 black silk sutures of the proximal edges of cut vagina and ileum. The incision was extended in stages circumferentially anastomosing the edges in each stage before cutting further, maintaining traction all the time so that the anastomosis was made as high up the loop of ileum and as low down the exteriorized vagina as possible. When the anastomosis was finally completed, and the long ends of traction sutures cut, the anastomosis immediately retracted 2.5-4 cm. from the skin edge of the introitus.

The length of the replaced segment varied usually between 6.0 and 8.0 cm. The vascular leash was next placed extraperitoneally and the pouch of Douglas peritoneum closed above the proximal anastomosis. The abdominal wound was then closed in layers.
One unit of 0.11% saline with 5% dextrose was given to each dog at operation and the intravenous cannula then removed.

**Post-operative care:**

The Foley's catheter was left in situ for 24 hours.

Penicillin and streptomycin was given intramuscularly for five days postoperatively, then oral furadantin 2 mgm/lb for one week.

Dilations were then undertaken at intervals of approximately two weeks and it was found that for the first few months there was a marked tendency to contraction at the anastomotic sites but this tendency decreased with time. The operative result is illustrated in Plates I and II.

**Variations:**

After the first series had been completed according to the prior description, it was found that, at copulation, the combination of the os penis, the bulbous swelling of the end of the penis during copulation, together with spasm of the sphincter vaginae, put too great a stress on the lower anastomosis which was situated just proximal to this sphincter. Most of the dogs who had copulated died the following day.

To test the type of replacement further, it was decided that the insertion of the urethra into the lower vagina would
1) Cervix 2) Upper anastomosis 3) Lower anastomosis 4) Terminal urethra 5) Introitus 6) Bladder

Plate I: The relationships of the ileal loop used to replace a segment of vagina.
Plate II: The relationships of the ileal loop used to replace a segment of vagina. The lower vaginal segment and the ileal loop have been opened to show the anastomoses and the urethral orifice.
have to be excised so that the lower vagina could also be excised and the lower anastomosis made to the skin of the introitus.

**Method 2:**
The next method tried was by a total cysto-urethrectomy with bilateral uretero-colic anastomosis. Vaginal replacement was then performed from cervix to the skin of the introitus. However, this dog suffered from a rather profuse, offensive watery diarrhea so was sacrificed.

**Method 3:**
A total cystectomy and bilateral ureterostomies were performed. This method was much more satisfactory but this animal suffered from a constant wetness of the abdomen and offensive odour.

**Method 4:**
The urethral orifice with a small cuff of vagina was dissected free from the vagina and sphincters and the lower end of the urethra was dissected free, including a large cuff of surrounding areolar tissue, leaving the junction of bladder and urethra undisturbed. Total vaginal replacement was then performed and at the conclusion of the operation the urethra was swung anteriorly and a urethrostomy performed.
in the lower end of the abdominal wound.

Two dogs were operated in this fashion. The first had excellent bladder function, passing a good stream with no incontinence but some terminal dribbling. This dog had been spayed so was sacrificed at three weeks. (Plates III, IV & V)

The second, because of difficulty in freeing the sphincter, suffered necrosis of the terminal 3/4" of urethra and vaginal cuff. Rather than attempt to rectify this situation, the dog was sacrificed.

Four more dogs were operated in this fashion, except that no attempt was made to take a cuff of vagina and the urethra was cut through healthy well vascularized tissue proximal to the sphincter remnants. The urethral remnant was then cut longitudinally for a distance of one cm. on opposite sides of the opening to allow a spout formation. Mucocutaneous anastomosis was performed with interrupted sutures of 000 monofilament nylon on an eyeless needle. Function of the bladder in these dogs was as good as in the first dog in whom the whole urethra and a cuff of the vagina was swung forwards.
Plate III: The appearance and position of the relocated urethral orifice. A number 18 French gauge catheter passed easily into the bladder.
Plate IV: The bladder has been opened and the urethra partially opened to show the curve of the relocated urethra. A number 18 French gauge catheter is in situ.
1) Cervix
2) Upper anastomosis
3) Bladder
4) Urethra
5) Lower anastomosis at introitus

Plate V: The relationships of the ileal loop used to replace the vagina after relocation of the urethral orifice. The loop has been opened to show the anastomotic lines.
RESULTS

There were no operative or immediate post-operative deaths in the series.

There were 21 dogs operated by the first technique. Four dogs killed in fights at the farm, four dogs sacrificed at intervals up to five months post-operatively, and one dog that died at five weeks were used as a group to follow the fate of the transplanted loop and anastomoses. All these dogs had well vascularised, intact ileal loops with well-healed anastomoses. There was no peritoneal reaction apart from some filmy adhesions and the anastomoses in the ileum restoring continuity were intact without any proximal dilatation. One dog had complete stenosis of the upper anastomosis while in all both upper and lower anastomoses showed a tendency to stricture.

The dog that died five weeks post-operatively was the first dog operated in this series, and the one in which the pubis was split with some resulting damage to the urethra. At post-mortem examination, the urine was found to be purulent with inflammation of the bladder and pelvis of the kidney.

Of the other 12 dogs, nine have died following copulation, in each case the lower anastomosis tearing posteriorly
and causing generalized peritonitis even though this area was well below the peritoneal reflection at operation. Two are still alive, one almost one year, and the other nine months, post-operatively.

One other dog of this group who had multiple enlarged tumor-like masses in both uterine horns at operation and who was intended for sacrifice at six months, gradually wasted and died just before the due date. At post-mortem these large masses were present with retained secretions and a mild peritonitis.

The one dog with bilateral ureterostomies is alive and well but still shows a tendency to stenosis at the sites of the anastomosis five months after operation.

Of the six dogs operated by the method of total vaginal excision and transplantation of the urethral orifice to the abdomen; one was sacrificed to check the feasibility of the operation; another was sacrificed seven days post-operatively because of necrosis of the terminal urethra with stricture and retention of urine; two others are dead and two alive. One of the two dead was a few weeks pregnant at operation and a trial labor was decided on at term. However, she died during the night and at postmortem the upper anastomosis was found
to be 2.5 cm. in diameter but obviously had not opened up at all to pass the foetal head. One dog died following anaesthesia for dilatation of the anastomosis, presumably due to hypersensitivity to the nembutal.

Because of the factors previously stated regarding the trauma of canine copulation with the os penis, globular swelling of the glans and the spasm of the sphincter vagina causing rupture of the lower ileum at copulation, it appeared that the dog was not an appropriate experimental animal for this investigation. For this reason a sheep was dissected and the colon found to have an arterial and venous supply suitable for fashioning a loop. Further, although the urethra again opens into the anterior wall of the lower vagina, as the sheep is a much more manageable animal frequent dilatations without anesthetic were possible and there was less likelihood of rupture because the penis of the ram is soft, filiform and does not become locked in the vagina.

One sheep was operated, excising the vagina between cervix and urethral opening and interposing a loop of colon. This operation in a sheep was found to be technically much more difficult than in the dog, because of a deep pelvis and broad pubis, but because of the previous experience with dogs
the technique was standard and the operation feasible. The sheep colon was also of much tougher consistency than the dog's ileum and of greater diameter. Two months after operation this sheep has a capacious vagina with only minimal tendency to stricture.

To proliferate and line the new vagina, maintaining potency with the use of tampons. This method has been revived from time to time; by Wells who used petrolatum gauze as a tampon, changing this every two days; by Kantor who used iodoform gauze for ten days, after which a dilator was worn for a variable time; by Wharton who used a balsa wood mold covered with a condom and who reported 12 collected cases with eight successes, three partial or complete failures and one result unknown; and by Bryan, Nigro and Counsellor who reported 14 patients treated by this method all of whom had excellent results. In two cases in whom biopsy was performed a month or more after the operation, squamous epithelium was growing and in one case in which immediate biopsy was done a similar result was found. They stated that the good results in these patients were possible because of the inherent ability of the newly formed artificial vagina to epithelialize itself. However, if there was difficulty in controlling bleeding or in elevating the peritoneum, or if the
Dupuytren in 1817, was the first surgeon to attempt the correction of congenital absence of the vagina. He made a passage between the bladder and rectum, using mainly blunt dissection and then allowed the epithelial buds in the tract to proliferate and line the new vagina, maintaining potency with the use of tampons. This method has been revived from time to time; by Wells who used petrolatum gauze as a tampon, changing this every two days; by Kanter who used iodoform gauze for ten days, after which a dilator was worn for a variable time; by Wharton who used a balsa wood mold covered with a condom and who reported 12 collected cases with eight successes, three partial or complete failures and one result unknown; and by Bryan, Nigro and Counseller who reported 14 patients treated by this method all of whom had excellent results. In two cases in whom biopsy was performed a month or more after the operation, squamous epithelium was growing and in one case in which immediate biopsy was done a similar result was found. They stated that the good results in these patients were possible because of the inherent ability of the newly formed artificial vagina to epithelize itself. However, if there was difficulty in controlling bleeding or in elevating the peritoneum, or if the
vaginal tract could not be opened up with ease, then a graft was used. When grafts are not used, epithelium probably arises from the lower segment of the vagina and also from buds of epithelium arising from remnants of the Mullerian ducts. However, in a later report, Counseller and Flor stated that when this was made a routine procedure failures occurred due to contraction and granulation.

Ayre took vaginal smears from an artificial vagina where no graft was used and showed the new lining to be reacting in a cyclic manner to ovarian hormones similar to the way the normal vagina reacts. Marshall stated that the disadvantages of this simple reconstruction procedure are that a large, raw granulating surface is present for two to three months, that secondary hemorrhages occur not infrequently, that there is local infection and that the procedure must be limited to those patients with a rudimentary vaginal pouch.

The next method to be tried in the correction of this type of defect was the use of free skin grafts. Heppner made the first attempt to use this method but apparently without success. Abbe used this method in the second of two cases he reported. In this case he made the space then took Thiersch skin grafts from the thigh sufficient to cover a thin
French rubber pouch stuffed with long strips of gauze. On the tenth day the plug was removed and it was seen that the grafts had taken and a new lined cavity had been created, four and a half inches deep.

Flynn, according to Flynn and Duckett, in 1915, used free skin grafts from the external genitalia to line the vaginal tract. An excellent result was obtained after repeated dilatations. In 1930 Kirschner and Wagner used a rubber sponge prosthesis covered with Thiersch grafts. The vaginal tract was drained by a rigid rubber tube which was inserted through the sponge. In eight to ten days the sponge was removed and dilatations were begun.

In 1938, McIndoe and Banister reported a case of the satisfactory use of a Thiersch graft over a vaginal mold which was left in place three to six months until the contractile phase of the grafting process was over, and this has become the standard method of vaginal reconstruction. They emphasized that previous reported methods of free skin grafting had partial or complete contraction occurring in a high percentage of the cases and that left to itself, free grafted skin uniformly undergoes a contractile phase less marked on convex surfaces where there is circumferential tension and most marked when this circumferential tension is poor or
absent, such as on concave surfaces or in body cavities. This phase lasts three to six months.

Thus, as a means of preventing contraction, intermittent dilatation is quite inadequate. They made the point that previous experience in the treatment of such conditions as the syphilitic nose, the obliterated buccal sulcus, the obliterated eyeocket, defects in the external auditory meatus and in some methods of hypospadias repair had shown that continuous mould pressure for long periods was necessary to ensure adequate take and absence of contracture of the graft. They then applied this principle to the problem of replacement of the vagina, using thin razor skin grafts $9\frac{1}{2}'' \times 2\frac{1}{2}''$ from the thigh, laid over a hollow vulcanite mould completely closed at both ends. The labia minora were then sutured to hold it in place and it was not removed for almost four months, and was then worn at night for a further six weeks. The result of this case was a vagina $5'' \times 2''$. They concluded from this case that the mould would be better left in situ for six months.

Loops of various regions of the intestine was the third method to be tried. Sneguireff reported a case in which he utilized a portion of the rectum in the formation of a new vagina. His operation consisted in making an incision through
the skin and subjacent tissues along the border of the lower portion of the sacrum and coccyx to the posterior border of the anus. The coccyx was resected, the rectum was separated from the anterior face of the coccyx, stripped from the surrounding parts, drawn into the incision, and ligated and divided. The superior portion was separated from the bladder, drawn down and sutured to the right of the resected coccyx. It (i.e. the superior segment of the rectum) was said to be surrounded by some fibres of the levator ani, and these were secured with it to act as a third anal sphincter. The upper end of the inferior segment was closed by continuous suture, forming the cul-de-sac or cavity of the new vagina. The results of the operation were said to be excellent, and union took place per primum. Fourteen days later, a second operation was done for the formation of the vulvar opening by incising the previous anus anteriorly and transforming the circular opening into a longitudinal one, surrounded by the labia minora and said to present a striking resemblance to the normal vaginal orifice. Union by first intention occurred. The vagina measured three inches in depth and was capable of a certain amount of contraction. There was apparently no faecal incontinence. She was reported one year later to have perfect control over the bowels and flatus, and to have
coitus in a normal manner.

Baldwin suggested utilizing for the lining of the new vagina the sigmoid flexure of the colon, or a loop from the lower end of the ileum. The abdomen was to be opened and the sigmoid seized at about its center by a pair of forceps introduced from below through the new canal and drawn down to the perineum. The length of bowel thus drawn down was next to be detached with the usual precautions, the continuity of the colon being at once restored by an anastomosis. One end of the vaginal loop would then be inverted and closed by a continuous suture, not penetrating the mucous membrane. By pulling up the fundus of any uterus present until the cervix was exposed in Douglas's cul-de-sac (or, if the cervix were absent, the opening into the uterus found), the other end of the bowel would be attached around the cervix by interrupted sutures to form a canal for the uterine discharges. The abdomen would then be closed in the usual way, with, if desirable, a drainage wick introduced from above downward through the new canal and just below the loop of intestine. Finally, the patient being placed in the lithotomy position, the apex of the doubled loop would be opened, the bowel cleansed as necessary, each limb of the loop packed with iodoform gauze, and the edges of the opening in the bowel attached to the
surrounding skin.

The gauze would be removed and replaced from time to time as necessary, and at the end of ten days or two weeks, the septum between the two loops was to be divided by clamp pressure.

He stated that such a vagina would be of ample size, would be lined with normal mucous membrane, would not materially contract, and would serve every purpose save that of child-birth; and it would hardly be prudent perhaps to absolutely deny the possibility of this.

He had no opportunity to try it at that time but reported a 38-year-old patient upon whom he carried out this type of procedure. He used the lower end of the ileum as this seemed to have the greater freedom of motion and also removed the uterus because it was rather fixed in position. Five months later her only complaint was that occasionally her bowels were a little loose and that there was at times a little difficulty in holding her urine, but she had apparently had this before her operation. Without having any knowledge of Baldwin's method, Mori in Japan in the same year formed a vagina by making an intestinal loop but without doubling it. Even two years after the operation the result remained satisfactory.
Popov used the ampulla of the rectum preserving the sphincter and Schubert modified Popov's method slightly so that this method is now usually called the Popov-Schubert method. The main technical aspects of this method are as follows. With the patient on the right side, the anus is circumcized and dissected from the sphincter. A longitudinal incision is made over the coccyx which is excised. The rectum is pulled forth by means of a dressing forceps and divided about 12 cm. above the anus. The upper end is dissected until the part which was cut through could easily be pulled down toward the anal region. The peritoneum is not opened. The proximal end of the lower segment was then closed and the cul-de-sac which had thus been formed was, by means of two sutures, fixed as high as possible to the sacro-spinous ligament. The piece of the anus which was cut out from the sphincter is drawn towards a newly formed orifice in the vulva by means of some traction sutures. The distal end of the superior segment of the rectum, which was closed with a clamp, was drawn through the sphincter ani and sutured to the sphincter and to the external anal skin by means of interrupted sutures.

Wagner reported a patient, treated by the Popov-Schubert method, who later became pregnant and delivered a
living 2,750 gm. infant through this reconstructed vagina before caesarian section could be performed.

Various modifications of replacement with intestine have been tried by other workers. For example, Judin used ileum but did not suture the sides of the two loops together and later crush them, but instead sewed the ends together so that he had a hollow closed intestinal ring. He later made a single opening into this loop. He quotes six personal cases treated in this way and states that four had a good deal of secretion, which is not surprising as the length of these loops varied from 20 to 40 cm.

However, because of the morbidity and mortality with operations on the intestine in the early part of this century, the method fell into disrepute. Judin quotes the figures of various workers of that time. He quotes 172 Baldwin operations with 28 deaths, a mortality rate of 16.3% and 123 Popov-Schubert operations with 10 deaths, a mortality rate of 8.1%. It is thus not surprising that these operations went out of favor and numerous attempts were made to find other applicable procedures. However, the change in outlook with the advent of modern methods of preparation of the intestine and surgical techniques is indicated by Schmid who quotes 20 personal cases of vaginal replacement with
sigmoid colon by the Baldwin technique with no deaths and no morbidity.

The forth method devised used thick skin flaps from the thigh. Beck\textsuperscript{6} opened the rectovesical space from above and below extraperitoneally. Two skin flaps from the thigh were raised, their free ends grasped by forceps introduced from above, drawn up and sutured to the depth of the space. The vagina was then packed.

Frank and Geist\textsuperscript{21} modified this procedure. They developed a tube pedicle graft three inches by six inches from the inner aspect of the thigh in stages, then detached the distal end and swung it in to line the vaginal cavity.

The fifth method devised for the treatment of this condition was by the use of labial grafts. Graves\textsuperscript{22} described this method, the basic points of which are as follows: a space is made in the recto-vesical region through a transverse incision. The two labia minora are then dissected throughout their length and flaps raised based at the clitoris. The labia are then split to form two "paddle-shaped" flaps. Two similar flaps are raised on the inner side of the thigh, based at the posterior angles of the artificial opening. The four flaps were then sewed together over a glass form and inverted into the recto-vesical space. He
later reported five successful cases.\textsuperscript{23}

\textsuperscript{13}Davis and Cron modified the Graves operation by raising only two flaps from the labia minora, based posteriorly. They reported two successful cases.

\textsuperscript{17}Falls described another variation of the labial graft procedure. He undercut a central disc of mucous membrane, two to three cm. in diameter, at the site of the rudimentary vaginal dimple, leaving the center of the disc attached to the underlying tissues. The recto-vesical space was then opened by blunt dissection and the disc of skin pushed inwards to form the vault of the new vagina. By making lateral cuts from the opening at three o'clock and nine o'clock and then making a "T" end to these incisions two to three cm. long, he made four short vulvar flaps. The free ends were then swung in and sewn to the disc forming the vault. The intervening raw surfaces became epithelialized in two weeks. After healing, this pouch is only two inches deep, but it may be deepened by the use of dilators and obturators or the whole process repeated. He reported four cases, three satisfactory and one partially satisfactory.

\textsuperscript{19}Frank, who had tried various methods of correcting this abnormality, found he could obtain good results simply by properly applied external pressure on the hymenal region,
and reported six patients treated in this way. He later modified this somewhat using three pyrex or thick-walled glass test tubes, 5/16, 5/8, and 3/4 inch in diameter and the larger two being six inches in length. He found that pressure properly applied for one half four, twice a day, was sufficient, and that the patient did not need to keep the tube inserted throughout the night as he had originally advised. A permanent vagina was established at the end of three months. He stated that the procedure was so simple, so effective and the result so uniformly successful that it should entirely supersede operative measures, and that it was merely an office procedure for instruction and mainly "homework" by the patient. Campbell found that she could lengthen the vagina to three inches (7.6 cm.) in two to four weeks by this method, but Emge thinks that more often than not this method results in a short vagina.

Various modifications of the above methods have been tried by numerous workers, but without any improvement in technique. For example, Caffier instead of using a skin graft to line the cavity, used foetal membrane from a patient delivered six hours previously. The membranes were kept in an ice chest till used because they tended to become offensive if kept at room temperature. There was a foul
discharge post-operatively and when the prosthesis was removed on the 9th day, none of the membrane could be identified but there were small islets of epithelium high up near the vault and there was epithelial spread from the orifice towards the cavity. Satisfactory epithelialization occurred in six weeks and the author stated that this method had the advantage of not subjecting the patient to the discomfort of a skin graft!

in a lined space so that continuous dilatation for up to six months post-operatively is necessary and regular dilatation thereafter is preferable. Therefore, it is usually recommended that reconstruction of an artificial vagina should be attempted only in patients who are married or are contemplating marriage in the very near future. Bryan et al. particularly stress this point in their discussion of 100 cases, stating that many of the cases in which the results were unsatisfactory were single women who would not wear the obturator indefinitely and could not have marital relations because of their unmarried status.

This leads to the rather unsatisfactory situation that young women in whom this condition is diagnosed are told to return for construction of a vagina if and when they are about to be married. This has the unfortunate result of making correction of the deformity dependent on an offer of marriage thereby emphasizing the abnormality and increasing
DISCUSSION

There is general agreement amongst most workers in this field that the McIndoe-Banister procedure is the procedure of choice in the average patient. It has the great advantages of simplicity, no mortality and minimum morbidity and short hospital stay.

Its great disadvantage is the tendency to contraction of the graft lined space so that continuous dilatation for up to six months post-operatively is necessary and regular dilatation thereafter is preferable. Therefore, it is usually recommended that reconstruction of an artificial vagina should be attempted only in patients who are married or are contemplating marriage in the very near future. Bryan, et al, particularly stress this point in their discussion of 100 cases, stating that many of the cases in which the results were unsatisfactory were single women who would not wear the obturator indefinitely and could not have marital relations because of their unmarried status.

This leads to the rather unsatisfactory situation that young women in whom this condition is diagnosed are told to return for construction of a vagina if and when they are about to be married. This has the unfortunate result of making correction of the deformity dependent on an offer of marriage thereby emphasizing the abnormality and increasing
any associated psychological problem.

As has been previously pointed out, patients presenting with haematometra soon after puberty must be treated immediately and in patients with an intersex syndrome, there is often a psychological problem and this can only be made far worse if adequate female genitalia are not constructed as soon as possible so that psychological adaptation of the patient as a "normal" female can be commenced immediately.

The operation of choice in these unusual circumstances seems to be some type of Baldwin procedure, replacing the vagina with a loop of intestine. The method has the marked advantages of requiring only one operation; of having no tendency to contract in the long axis, so that it may be performed before puberty and still be a functional vagina years later; of not requiring any secondary procedures such as regrafting; of not deforming adjacent areas; of not requiring continuous dilatation; and of forming a moist flexible elastic vaginal tube. It also has the great advantage of being readily adaptable to the problem of connecting a functional uterus to the exterior.

The major disadvantage of this technique has been the high mortality with other minor disadvantages of excessive secretion if ileum is used, particularly if too long a loop
is used, and the fact that it may occasionally be unsuitable due to the type of vascular supply or to the shortness of the mesentery.

The early prohibitive mortality collected by Judin has previously been quoted. However, the change in results of bowel surgery is well illustrated by the experience of Counseller, who with McIndoe has pioneered the consistently successful treatment in the usual case using the Thiersck graft method. In 1949, he and others reported one hundred cases of congenital absence of the vagina treated in various ways, and 14 of whom were treated by a Baldwin operation using ileum. Four of these patients died in the hospital of peritonitis or intestinal obstruction. The average length of time between operation and follow-up in this group was more than eight years, but as the average for whole series was only four years, this indicates that these were early patients in the series. They concluded then that with the Baldwin method the mortality was high (28.6%) and that there was a high incidence of irritating discharge and morbidity. In 1957, Counseller and Flor presented a new series of 43 patients in whom they used the Baldwin type of operation in four instances of failure of a previous McIndoe type of reconstruction due to scarring and contraction. In three
cases they used ileum and in one sigmoid, all with excellent results and state that as this type of operation had been made much safer with the use of antibiotics, it could now be considered again for use as a secondary measure. They also make the point that this operation should not be attempted except by surgeons who are expert in intestinal surgery.

Schmid in 1955 reported 20 personal cases of reconstruction using the sigmoid flexure with no mortality or morbidity. These cases had no troublesome secretion and no shrinkage of the loop though in some cases there was a slight degree of stenosis at the site of anastomosis of the mucus membrane of the loop and the introitus. He stated that formation of the vagina using small gut is to be avoided because of its great primary mortality.

The experimental material in this series further illustrates the fact that with modern methods of bowel surgery there should be no mortality and minimum morbidity due to the operation itself even using small gut. In this series of 30 operations there were no operative or post-operative deaths or morbidity which could be attributed to the intestinal transplantation part of the procedure. The basic techniques used are the same as those used in other types of intestinal transplantation, for example ileal replacement
of the ureter or uretero-ileostomy: care to obtain an adequate vascular supply to the loop; a large marginal artery and vein; avoidance of tension on the vascular leash; and the placement of the vascular leash and the anastomoses in a retroperitoneal position. All these factors plus basic pre- and post-operative care now make these safe procedures.

In this experiment due to the mechanical factors involved with these experimental animals, copulation frequently caused death of the animal. However, in this type of operation reported over the years on humans, copulation in those surviving the operation has been satisfactory and no death has been reported in the literature due to this cause. It would thus seem that, under conditions of stress illustrated by copulation in dogs because of the smallness of the calibre of the ileum and the thinness and weakness of its wall, there is a marked tendency for it to tear. Because of this evidence and the occurrence of excessive secretion from the ileum, a loop of sigmoid colon would seem to be far preferable to a loop of ileum for use in vaginal reconstruction. However, if, because of shortness of the mesentery or unsuitability of the vascular supply, the sigmoid cannot be used, then ileum may be used but with the following provisos—a loop should be taken, doubled and joined by a side-to-side enteroenterostomy
so that a double lumen ileal vagina is formed; this loop should only be of length sufficient to form this double loop for the normal vaginal length; and the previous technical safeguards should be carefully observed.

McIndoe-Banister method using Thiersch grafts on a mold with continuous post-operative dilation till all tendency to contraction has passed.

In certain unusual circumstances, such as patients presenting soon after puberty with haematometra or patients with vaginal aplasia or an intersex state and major psychological problems, early definitive replacement is indicated.

In these patients replacement with a loop of sigmoid is indicated, and if the sigmoid is not suitable, a doubled loop of ileum, as short as practicable, may be used.

No conclusions regarding the manner in which fertility is affected could be deduced from this experiment.
SUMMARY

The replacement of the vagina in the usual patient with vaginal aplasia is most safely and easily performed by the McIndoe-Banister method using Thiersch grafts on a mold with continuous post-operative dilation till all tendency to contraction has passed.

In certain unusual circumstances, such as patients presenting soon after puberty with haematometra or patients with vaginal aplasia or an intersex state and major psychological problems, early definitive replacement is indicated. In these patients replacement with a loop of sigmoid is indicated, and if the sigmoid is not suitable, a doubled loop of ileum, as short as practicable, may be used.

No conclusions regarding the manner in which fertility is affected could be deduced from this experiment.
REFERENCES


14) Dupuytren (1817). Quoted by Marshall, H. K.


27) Heppner (1872) as quoted by Marshall, H. K.


32) Kirschner, M., and Wagner, G. A.: Quoted by Barrows, D. N.


37) Mori (1910): Quoted by Marshall, H. K.


