STUDIES ON PERITONEAL ADHESIONS.

WITH A CONTRIBUTION TO THE TREATMENT OF DENUDED BOWEL SURFACES.

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THE problem of peritoneal adhesions is one that merits the serious consideration of everyone engaged in abdominal surgery. That this fact is generally recognized is indicated by the large number of valuable contributions to the subject—including not only elaborate experimental researches of the most diversified sort, but also carefully recorded clinical observations—contained in the literature of the past twenty-five years. The results of all this work have been both gratifying and disappointing; gratifying in so far as certain valuable procedures have been both scientifically and empirically established, but disappointing in that the work is still unfinished, and is, indeed, in a state of confusion as regards the actual worth of numerous procedures very commonly employed and from time to time enthusiastically advocated; often it appears, without adequate scientific justification.

It is the purpose of this communication to present a collective and analytical review of this voluminous literature, classified along practical, common-sense lines, to impartially weigh the evidence, and to draw such conclusions as seem warranted. In connection with this critical study I shall describe a new and original method of dealing with denuded bowel surfaces.

Much of the existing confusion could have been avoided, it seems to me, if investigators had kept in mind the fact that peritoneal adhesions, like bacteria, are of two kinds—those which are useful and of essential worth to mankind, and those which are harmful and inimical to life or health. They represent in every instance nature's best method of defense or

of repair. Moreover, as we shall see later on when we come to consider the pathological processes involved in their formation, it is highly probable that they will always remain a necessary part of abdominal surgery, and that we can never hope to discover a prophylactic or curative agent that will prove to be a panacea for all cases. Indeed, it seems to me that efforts along this line are fundamentally wrong, and that they represent misdirected energy. For whenever and however the peritoneum is injured it must be repaired, if the individual is to survive. But the very processes involved in this repair include, in many instances, the necessity of adhesion formation. The search after some specific and potent remedy for this, therefore, represents no less ambitious an undertaking than to provide nature with a substitute method of repair in the peritoneal cavity that possesses improvements over her own! Now it is very obvious that this is impossible, and that the abdominal surgeon must accept the inevitable, and equip himself to reckon intelligently with peritoneal adhesions as a vexing but necessary part of his work. It will be found in the last analysis that he has recourse to three classes of procedure: (1) measures which prevent adhesions; (2) measures which restrict their formation to the harmless variety; and (3) measures which aid in their absorption.

Before discussing systematically the various procedures belonging to each of these classes, let us recall briefly several characteristics of the peritoneum itself which have an important bearing upon this problem.

First of all, we are apt to forget the enormous area of this serous membrane which has been estimated to be only slightly less than that of the skin. Again its remarkable absorptive power is so striking that it has actuated a number of investigators to undertake elaborate and laborious researches to determine its mechanism. It is conceded by all that the lymphatic absorption is most active in the upper part of the abdomen, especially on the under surface of the diaphragm and in the omentum, while in the pelvis it is relatively sluggish —a fact now commonly taken advantage of by surgeons in

the use of the Fowler or sitting posture in the treatment of peritoneal infections. Furthermore, it is generally admitted that solid particles—such as coloring matter in suspension, bacteria, oil globules, etc.—are taken up by the lymphatics. But concerning the process of absorption of fluids and soluble substances, there is some difference of opinion as to whether it occurs through the blood-vessels or the lymphatics. Starling and Tubby[1] introduced into the peritoneal cavities of dogs salt solution colored with indigocarmin, and methylene blue, and noted the time of its appearance respectively in the thoracic duct and in the urine. They found that it appeared much earlier in the urine, from which they concluded that the absorption had been through the blood-vessels. Mendel[2] later confirmed these observations, using the same methods. Hamburger[3] studied the effect of ligating the left innominate vein —*i.e.*, practically the thoracic duct— upon absorption of fluids of different osmotic pressures introduced into the peritoneal cavities of rabbits, and concluded that the lymphatics play a very small part in the process of absorption. Orlow[4] concluded that the blood capillaries are the essential paths of fluid absorption. By introducing a measured quantity of fluid into the abdominal cavities of dogs and withdrawing the remainder after a few hours, he observed invariably that a large amount had been absorbed, while the flow of lymph through the thoracic duct, measured before introducing the fluid and after its withdrawal, remained the same. Heidenhain[5] corroborated this work, and reached the same conclusion. Cohnstein[6] noted some increase in the flow of lymph from the thoracic duct after introducing fluid into the abdominal cavity, but thought it entirely out of proportion to the amount absorbed. His results in the main, however, agree with those of Orlow and Heidenhain. Klapp[7] also concluded from his experimental work on dogs that soluble substances are absorbed from the peritoneal cavity chiefly through the blood-vessels. This imposing array of evidence seems quite convincing until one comes to consider the contribution of Meltzer[8], who, contrary to Starling and Tubby and Mendel, observed that solutions

of coloring matter introduced into the peritoneal cavity appeared earlier in the thoracic duct than in the urine, and especially the more elaborate communication of Adler and Meltzer.[9] These authors concluded from numerous experiments that ligation of the lymphatic ducts in rabbits does exert a restricting influence upon the quantity of fluid disappearing from the abdominal cavity, but that such experiments do not indicate whether or not the lymphatics carry away a part of this fluid. They found further that potassium ferrocyanide and strychnine are carried away mainly, if not exclusively, by the lymphatics. Their criticism of the work of Hamburger, Orlow and Heidenhain is, it seems to me, well-founded; and I quite agree with them that the conclusions of these authors are not justified from their work. They very cleverly point out the possibility of the interstitial tissue spaces as a system to be considered independently of the blood-vessels and the lymphatics, into which fluid may enter from the peritoneal cavity by filtration and osmosis; that from here it has three avenues of escape: (1) it can spread into the interstitial spaces of neighboring regions, and either not affect the blood- and lymph-vessels at all, or affect the blood-vessels sufficiently to reduce transudation into this region; (2) it can enter the blood-vessels through the walls of the capillaries or veins; (3) it can enter the lymphatics through the walls of the lymph capillaries. They call attention further to the fact that the contents of the thoracic duct may be quite different from the tissue fluids, the latter being a mixture of at least three components, viz., transudate from the blood-vessels, this minus the elements used in anabolism, and the products of catabolism. It becomes evident, therefore, that the interstitial tissue spaces may be conceived of as a system of reservoirs into which fluids or solutions of coloring matter are poured from the peritoneal cavity, probably largely by filtration and osmosis; and further, that the conclusions of Hamburger, Orlow, Heidenhain and others, based upon experiments which assume that the disappearance of these substances from the peritoneal cavity is equivalent to their direct and immediate transfer either to the lymph or

blood capillaries, and which utilize the flow of lymph through the thoracic duct as an accurate indicator of the extent to which the lymphatic system participates in the process of absorption, are entirely unwarranted.

It seems to me highly probable that both the lymph and blood capillaries participate in the removal of fluids and soluble substances from the interstitial spaces, but that the experimental work thus far done does not warrant a dogmatic statement that either system is entirely concerned in the process to the exclusion of the other. It must be remembered, too, that it has been repeatedly shown that the pressure in the peripheral veins is considerably greater than that in the lymphatic vessels—the latter constituting a system of drainage channels with a pressure approaching that in the great vessels near the heart; and that the pressure in the interstitial spaces is probably somewhere between that in the peripheral veins and the lymphatic vessels; a fact which acquires added significance when it is undertaken to show that the chief absorption of fluids is through the venous channels.

In this connection it is well to recall further that it has now been definitely established through the work of MacCallum,[10] Kolossow,[11] Muscatello,[12] and others that the endothelial covering of the peritoneum is continuous, and not perforated by numerous *stomata* and *stigmata,* or direct channels of communication between the peritoneal cavity and the lymphatic vessels, as was until quite recently generally taught.

Closely allied with its remarkable absorptive power, is the well-known ability of the peritoneum to successfully cope with an astonishing amount of infection without itself being seriously or permanently damaged. It has been repeatedly shown that enormous numbers of virulent bacteria in pure culture can be injected directly into the peritoneal cavities of dogs without producing any serious consequences. And, as everyone knows, during the course of a large percentage of abdominal operations the peritoneum becomes soiled with bacteria, the destruction of which the surgeon confidently leaves to nature. Another familiar characteristic of the peri-

toneum is the remarkable variation in sensibility exhibited by different portions—in a general way the visceral part being entirely insensitive to pain, pressure, heat and cold, while the parietal portion is everywhere exquisitely responsive to these sensations. This was elaborately worked out by Lennander.[13] Cushing[14] had previously called attention to the fact that this same difference holds true for inflamed as well as healthy peritoneum, an observation that has been frequently corroborated by others since. Samson [15] observed during the course of operations upon the lower end of the ureters that they are painless when pinched, cut, or sutured, unless traction is exerted on the parietal peritoneum. Broese[16] very recently corroborated Lennander's views with reference to the pelvic organs in a most convincing way. In a case of vaginal fixation of the uterus, done under local anæsthesia, he found that the ovaries, tubes, and body of the uterus are insensitive to pain, pressure, heat, and cold. He amputated the tube and resected the uterine cornua without discomfort to the patient. But any traction, such as was required to deliver the uterus into the vagina, was extremely painful. Mitchell[17], whose large experience in laparotomy under local anæsthesia entitles him to speak with authority upon this subject, has just published an excellent review of the literature of the past ten years, together with some very interesting observations of his own. It is quite evident from his paper that the controversy is still going on actively between the adherents and opponents of Lennander's views. His conclusions accord with the latter, and furthermore, he met with an encouraging measure of success in systematically analyzing abdominal pains before laparotomy, in an effort to diagnosticate both the location and the cause of this sensation. The recently conducted elaborate dissections of Ramström[18] have gone far toward furnishing us with the much-desired anatomic basis for this remarkable difference, so strikingly shown in the course of laparotomy under local anæsthesia. If post-operative adhesions are oftentimes unavoidable, let us, therefore, in the light of these observations, strive to limit their formation to the viscero-

visceral, rather than the visceroparietal variety, for the double reason that the former are not only painless but, generally speaking, far less dangerous.

One of its most striking characteristics is the rapidity with which the peritoneum can form adhesions—a piece of gauze introduced into the abdomen during the course of an operation becoming quite snugly fixed to the visceral surfaces within a period of twenty minutes; a fact that is daily taken practical advantage of by surgeons in the disposition of protective gauzes during operations upon infected areas, and which adds materially to the sense of security afforded by gauze pads alone. This characteristic is also very intimately involved in the whole question of peritoneal drainage; and it constitutes further one of nature's admirable methods of protection against disastrous peritoneal damage, as exemplified in the walling off of an appendix abscess.

Finally, perhaps less striking but to my mind even more remarkable, is the completeness with which the peritoneum may absorb adhesions, and, indeed, completely eradicate all traces that would indicate their previous existence. I am convinced that it is a perfectly safe assertion to make that adhesions invariably follow laparotomy, and yet how common it is nowadays to find at a later second laparotomy no traces of them whatever.

Now, obviously, all of these fundamental and important characteristics of the peritoneum must be reckoned with in studying the process of adhesion formation and in any attempt to control or prevent it. Happily we now know, as a result of much careful experimental and clinical study, quite accurately the pathological changes involved. Wegner,[19] in 1877, made a lengthy report of elaborate researches into the histological changes occurring in the peritoneal endothelium under a variety of experimental conditions. One rather unique experiment of his was to blow air into the peritoneal cavities of rabbits over a period of one month, observing the effects after varying intervals of time. He found fatty changes in the endothelium after four days, which later—after eight or

ten days—changed to scar tissue, but produced no adhesions. Graser[20] described in detail, with illustrations, the early histological changes occurring in aseptic wound healing of the peritoneum. He showed that after injury to the endothelium, the denuded surfaces lie together by reason of the agglutinating properties of the exudate, which later, through the growth of spindle-cells, becomes changed into vascularized connective tissue, and terminates in the parts becoming grown fast together. More recently Hertzler[21] published observations on the formation of peritoneal adhesions made in a rather novel way, namely, through a small glass window sewed into the abdominal wall of the animal. He concluded that peritoneal surfaces may agglutinate without destruction of the endothelial layer; but that in true adhesions the endothelium is always destroyed. If, however, the basement membrane is not destroyed also, he believes that the adhesions may later separate; otherwise, the union is rendered permanent through the formation of fibrous tissue. It would seem, therefore, that the pathological changes involved in the process of adhesion formation in the peritoneal cavity are, in order of sequence: (1) injury or death of the surface endothelium; (2) pouring out of coagulable exudate; (3) agglutination; (4) organization; (5) fibrous tissue formation, which terminates ultimately in (6) a contracted scar. Observe that the whole process is dependent upon and subsequent to injury to the surface endothelium.

It is not surprising, then, to find the bulk of the literature on the etiology of adhesions concerned with a study of the various agencies ordinarily coming in contact with the peritoneum that might be considered inimical to the vitality of its endothelium. For the sake of brevity and clearness we may classify these contributions according to subject-matter as follows: (1) blood; (2) sutures and ligatures; (3) eschar of the thermocautery; (4) air; (5) infection; (6) mechanical, chemical and other agents.

Blood.—The final verdict has not yet been given regarding the relationship of free blood in the peritoneal cavity to ad-

hesion formation. Penzoldt[22] published, in 1876, the results of a very elaborate experimental research into the fate of large amounts of blood in the peritoneal cavity, showing that it is absorbed. Wegner[19], in 1877, and later Vogel[23] observed the same thing experimentally. V. Dembowski[24], in 1888, reported the results of a large number of carefully executed experiments on adhesion formation in the peritoneal cavity, and concluded with reference to blood-clots, that they do not provoke adhesions. Gersuny[25], on the other hand, after studying a group of cases exhibiting a constant type of adhesion about the sigmoid ("flexur adhesion"), thinks that bleeding from ovulation or tubal menstruation may be the cause. Zweifel[26] and his school—*vid.* Füth[27]—strongly advise the removal of all blood from the peritoneal cavity in cases of ruptured ectopic pregnancy. Fromme[28] reported, a few years ago, the results of very elaborate and painstaking experiments on rabbits designed to test, (1) the effect of blood alone, and with serous defects in the peritoneal cavity; and (2) of infected blood alone, and with serous defects; using for this test pure cultures of common bacteria. He concluded that in the vast majority of cases neither blood alone nor with peritoneal defects produces adhesions. Furthermore, some of the cases with infection added showed none, although the majority of these did develop adhesions, especially those with raw peritoneal surfaces. Fromme quotes Biyl as having reached the same conclusions experimentally a few years before. Flateau[29] opposes the views of Zweifel's school, and leaves all the blood in the peritoneal cavity in cases of ruptured extra-uterine pregnancy that does not escape as a result of necessary operative manipulations. He condemns all efforts to remove it on the ground that it is impossible to get it all out, and that attempts to do so only serve to prolong the operation and to injure the peritoneum. Baisch[30], on the basis of his experimental work, concurs with the view that the peritoneum is capable of absorbing large amounts of blood without resulting adhesions, if intact, but finds that whenever a serosa-free surface is present it always leads to adhesions.

My own experience leads me to believe that the blood originating from rupture or abortion in cases of ectopic pregnancy does not produce peritoneal adhesions. The pelvic adhesions so commonly found in these cases are to be explained much more rationally, it seems to me, on the probability of associated or pre-existing infection, or as attributable to irritation induced by the development of the gestation sac. I have frequently observed cases in which the abdomen had been filled with a mixture of blood and serous exudate for periods of twenty-four hours or longer, and yet at operation it was seen that the peritoneum had not even lost its gloss. It is my deliberate judgment, therefore, that blood alone does not cause peritoneal adhesions, but that when it is associated with infection or trauma, its presence is to be regarded as an adjuvant to their formation.

Sutures and Ligatures.—The ultimate fate of aseptic sutures and ligatures in the peritoneal cavity and their relationship to adhesion formation have been carefully studied by a number of workers. Hallwachs[81], in 1879, showed with good experimental work that non-absorbable sterile ligatures in the peritoneal cavity first produce a circumscribed inflammatory reaction, then become covered with a thin layer of granulation tissue, and being thus isolated from surrounding structures, become gradually disintegrated and are removed through the agency of the tissue juices and leucocytes. Spiegelberg and Waldeyer[82] had earlier, in 1868, noted the harmlessness of aseptic ligature material in the abdomen. Rosenberger,[83] Tillmans,[84] tenBrink,[85] Kelterborn[86] and others later confirmed these observations. V. Dembowski,[24] on the contrary, concluded from his experiments that all sutures act as foreign bodies and cause firm adhesions along their lines of insertion; but his work was not convincing to later investigators. Stimson,[87] in 1889, called attention to the dangers of mass ligatures, and recommended substituting individual ligation of vessels in pedicles, and covering the latter with peritoneum. Klotz[88] found in six cases relaparotomized for ileus each time a loop of small bowel adherent to a pedicle stump. I

recall very distinctly a case of post-operative ileus, observed a few years ago during my hospital apprenticeship in the department of Dr. H. A. Kelly at Johns Hopkins Hospital. A simple interval appendectomy had been done by one of the members of the House Staff. The usual technic of the department had been employed—*i.e.*, amputation by the clamp and cautery method, inversion of the stump, and securely tying a purse-string suture previously placed about the base. Only, in this instance, owing to the insignificant size of the meso-appendix pedicle stump, the usual custom of covering it over had been omitted. At the second operation, performed within forty-eight hours, I found a band of omentum quite snugly fixed to this little mesenteric stump and obstructing the ileum. Rubin[39], in his report of an elaborate pathological and experimental study of the functions of the great omentum, published only a few months ago, concluded, with reference to omental adhesions to the abdominal incision, that they are best prevented through a carefully introduced continuous catgut suture. Neuhof and Wiener [40] also very recently published the results of a most interesting and instructive experimental study of omental adhesions. They showed that the omentum is capable of insinuating itself into needle punctures, and through the small gaps between peritoneal sutures, and of adhering to these minute raw surfaces. It is obvious how easy it would be for a less careful observer to attribute such findings to the presence of the suture itself. It seems to me definitely proven, then, that when one exercises good surgical judgment in the choice of aseptic sutures and ligatures, and manual dexterity in their application, together with proper attention to covering up pedicle stumps, no grave fears need be entertained as to troublesome adhesions arising from this source.

Eschar of the Thermocautery.—The results of the experimental work on the use of the thermocautery in the peritoneal cavity have been somewhat conflicting. Thus Spiegelberg and Waldeyer,[32] v. Dembowski,[24] Franz,[41] and Maslowski[42] found that it produces adhesions. Baisch[50] and Kelter-

born,[86] on the other hand, were unable to confirm this work. TenBrink[85] produced adhesions with the cautery only when infection was present. Küstner[43] reports in detail a case in which a large ovarian cyst, with many pelvic adhesions, was removed, the actual cautery being used to sever the adhesions and also the pedicle of the cyst. At a second operation fourteen months later for post-operative hernia no adhesions were found where the cautery had been used. A possible explanation of these conflicting reports is to be found in Vogel's[23] excellent monograph. He found that a superficial burning of the peritoneum generally gives rise to adhesions, but that none occur after a thorough cauterization with the formation of a thick eschar. As long ago as 1877, Wegner[19] explained the formation of peritoneal adhesions as analogous to healing by first intention, and Vogel, with this idea in mind, ascribes their failure to materialize, after a deep eschar or a severe chemical injury is produced, to the fact that the layer of necrotic tissue prevents primary union; or, in other words, the charred surface protects the underlying granulations from contact with neighboring structures long enough for them to become covered with new endothelium. Webster[44] corroborates Vogel's claims, and advocates very thorough cauterization to produce a black char. Whether or not this explanation is correct, the weight of experimental and clinical evidence certainly warrants the thorough application of the cautery when indicated, with far less likelihood of adhesions ensuing than if certain other procedures applicable to the same conditions are substituted.

Air.—Exposure of the viscera to the air is recognized, of course, as one of the cardinal factors in the production of surgical shock. It may not be so generally known, however, that very elaborate and interesting experiments have been carried out to ascertain the exact effect of air on the peritoneal endothelium and its relation to adhesion formation. Reference has already been made to Wegner's unique experiment of blowing air into the peritoneal cavities of rabbits over

varying periods of time, thereby producing decided changes in the surface endothelium, even to complete substitution by scar tissue, but observing no signs of adhesions develop. Walthard's[45] experiments have been much quoted in this connection, because of the great care and thoroughness with which they were conducted. No one can read this communication without being impressed by these facts, as well as by the significance of his conclusions. In his first series of experiments he performed supravaginal hysterectomy on a number of rabbits, carefully avoiding mechanical injury to the peritoneum of the uterovesical pouch by not touching it at all; he freely exposed it to the air, however, and at the autopsies, some days later, he found adhesions in every case between the surfaces of the uterovesical peritoneum. In the next series he brought the uterus out through a laparotomy wound, and very carefully protected it, as well as the surrounding parts, with gauze pads moistened with hot salt solution; he kept the moisture, temperature, and protection as nearly constant as possible. At the end of the experiment the uterus was returned to the peritoneal cavity and the wound closed. Later post-mortem examinations showed no adhesions and no exudate in any case. Next he tested in cats the effect of air contact on isolated areas, by exposing a loop of bowel, part of the omentum, or the posterior part of the bladder peritoneum to the air for twenty minutes. Twelve days later at autopsy every case showed adhesions between the bladder peritoneum, omentum, and incision. The intestine, however, did not adhere in any of these animals. In an equal number of control animals, protected with moist hot gauze, no adhesions occurred. In a very ingenious way he then exposed the peritoneum to air filtered free of dust and infection, and found that adhesions resulted under absolutely aseptic conditions. He then tested the effect of steam at 38° C. on the peritoneum and found that it produced no adhesions. Next he tested the chemical action of component parts of the air (O—Co_2—N) and found that none of them produced adhesions, if moisture was present. Dry air at 38° C.

produced both adhesions and macroscopical changes in the peritoneum. He concluded from these results that the damaging influence of air on the peritoneum is not dependent upon the presence of dust and infection, but when freed from these and in a state of dryness, its prolonged contact with the normal serosa produces a necrosis of its endothelium by cooling, with resulting contraction of the blood-vessels and consequent diminished nutrition, leading finally to adhesion formation. He believes, further, that long exposure to air lowers the resistance of the peritoneum, so that the number of bacteria necessary to produce fatal peritonitis is greatly reduced. His experimental deductions are borne out clinically in 146 laparotomies on human beings for various causes, in that not only no adhesions clinically discoverable occurred, but also much less post-operative flatulence was seen. The year following Walthard's publication Schiffer[46] reported from Sanger's clinic a marked falling off of ileus cases following the introduction of moist asepsis. In 132 laparotomies with dry asepsis, there were 10 deaths, 5 of which were due to intestinal obstruction. In 76 cases with moist asepsis there were *2* deaths—both cases of ruptured ectopic pregnancy—and no ileus. He further noted much less post-operative discomfort, vomiting, and thirst. A few years later Uhlmann's[47] paper appeared based upon a very careful study of the material of Zweifel's clinic, and contradicting every essential point claimed by Walthard and Schiffer. Thus flatus was passed on the second day by both the dry and wet aseptic cases. Likewise the bowels moved on the third day alike in both classes of cases. Only one fatality from ileus occurred in 481 laparotomy cases with dry asepsis, although 18 (3.3 per cent.) of these did have intestinal disturbance; while in 80 cases with moist asepsis, 4 (5 per cent.) had severe intestinal disturbance. Operative peritonitis with death occurred in 0.6 per cent. of the cases during the period of dry asepsis and 1.25 per cent. during that of moist asepsis. Flatus passed and the bowels moved within the same period of time both in those cases which were eventrated

at operation, and those in which the intestines were left *in situ* —a fact which the author thinks casts doubt on Walthard's idea of deleterious effect of the air drying the peritoneum. In 23 cases relaparotomized—some of whose first operations had been done with antiseptic, some with dry aseptic, and some with moist aseptic technic—post-operative adhesions were found, but were always to be accounted for by trauma, and nowhere were adhesions found between two serous surfaces entirely uninjured at the first operation. Adhesions between loops of bowel were not more frequently encountered in the cases that had been eventrated than in the others of the relaparotomized series; a fact which the author thinks disposes of Walthard's idea of air damage. Furthermore, no connective-tissue thickening of the serosa was found in places where the surfaces were damaged at the first operation, but did not lie in contact long enough to adhere, and Uhlmann thinks that this does not occur when only the endothelium is injured. Although adhesions were found in all of the 28 cases relaparotomized, only 6 of these had shown intestinal disturbances—a fact which the author thinks shows how inaccurate the test of intestinal obstruction is as an index of the frequency of adhesions following any special operative procedure. He finds support of his criticism of Walthard's ideas in Fritch's[48] report of 52 laparotomies conducted with moist warm aseptic technic, furnishing two cases of ileus with one fatality, and concludes that the claims of Walthard and Schiffer are not proven, and should be tested further before the older methods are abandoned.

Now, in drawing conclusions from these reports as to the relative value of moist and dry asepsis, it must not be forgotten that nothing brought out in this clinical study of Uhlmann's invalidates in the least the experimental results of Walthard. It is of fundamental importance, too, to remember that the formation of post-operative adhesions does not depend solely upon the principles of technic involved respectively in moist and dry asepsis. Before a just comparison can be made clinically of results obtained by the two methods, there-

fore, it becomes necessary to exclude absolutely all other factors involved in the production of adhesions. It is manifestly illogical to throw together two heterogeneous groups of cases that have been laparotomized for a variety of conditions, and to ascribe the resulting difference in adhesion incidence solely to the factors involved in dry and moist asepsis. Such studies as those of Schiffer, Fritch, and Uhlmann, therefore, while furnishing most interesting and instructive data, are of very little value in determining the point at issue; and it seems to me that Walthard's experimental results render it imperative that surgeons should employ moist asepsis as far as practicable in the abdomen, at least until they are more successfully assailed than by the criticisms thus far brought forward. Thus, aside from shock, we have an additional very important reason for carefully protecting all parts of the peritoneum from undue exposure during the course of abdominal operations, namely the prevention of adhesions.

Infection.—No one doubts, of course, that infection produces adhesions. But there seems to be much difference of opinion as to the formation of adhesions without infection. Martin[49], as far back as 1888, made an exhaustive study of a series of cases requiring relaparotomy, and called attention to the increased difficulties of the second operation on account of intestinal adhesions to the anterior abdominal wall so commonly encountered. A number of observers—v. Velits,[50] Koblanck,[51] Huth,[52] Pernhorst,[53] Steffens,[54] and others—have since called attention to the gradual falling off in the number of adhesion cases seen in the clinics corresponding with the improvement in surgical technic. Some have interpreted the remaining incidence, however, as conclusive evidence that our methods are still imperfect as regards asepsis. Steffens's excellent contribution, based on a very thorough study of 45 patients relaparotomized, is worthy of more than passing notice. He found that more or less general adhesions were encountered at the second laparotomy in every case that had exhibited an elevation of temperature following the first operation. Pernhorst also noticed this fact, and thinks that

post-operative elevation of temperature is an indication of adhesion formation. Fritsch[48] showed from a study of re-laparotomized patients that adhesions occur in spite of the most careful technic. Reichel[55] concluded from an elaborate experimental, clinical, and bacteriological study of ileus that infection is the chief cause of this condition, and that it may produce very few clinical symptoms, and little or no change in the peritoneal surface. He thinks that the infection may be limited to one loop of bowel, and that the resulting interference with peristalsis is the chief cause of adhesions. Kelterborn's experiments led him to believe that peritoneal adhesions are due to infection always. V. Braun-Fernwald[56] and also Jesset [57] later came to the same conclusion. The year following Kelterborn's report, Thompson[58] published the results of a large number of experiments on cats, dogs, and rabbits, carried out with the most elaborate precautions against all possible sources of infection, even going so far as to sterilize the air of the operating room. He found that omental and intestinal adhesions follow perfectly aseptic laparotomies, even when the abdominal wound is shown to be sterile. Fromme believed, from his very creditable experimental work, that peritoneal adhesions are due chiefly to infection, but that they can occur without it. The work of the several investigators referred to in the last section is in full accord with this idea. It is evident, therefore, that the alignment can be sharply drawn between the adherents of two views: (1) those who hold that infection is the sole cause of peritoneal adhesions; and (2) those who believe infection to be a frequent cause, but contend that adhesions will also result from a variety of other causes acting independently or collectively. To my mind the evidence given above establishes beyond doubt the correctness of the latter view.

Mechanical, Chemical and Other Agents.—During the period of transition from antiseptic to aseptic surgical technic, considerable discussion is to be found in the literature regarding the relationship of the former to adhesion formation in the peritoneal cavity. V. Dembowski [59] claimed to have in-

jected strongly irritating substances, *e.g.*, turpentine, into the abdomen without producing adhesions. He was also unable to produce them by such violent mechanical irritation as rubbing the peritoneal surface with a stiff tooth-brush; and even after deliberately excising islands of peritoneum together with the underlying fascia, he caused no adhesions. The omentum was adherent to the abdominal scar, however, in all of his animals; and he found, further, that gauze or other foreign bodies, introduced into the peritoneal cavity, always produced adhesions. Delbet, Grandmaison and Bresset,[60] on the other hand, published in 1891 the results of experiments which demonstrate very clearly the harmfulness to the peritoneum of such antiseptic solutions as carbolic and salicylic acids, bichloride and biniodide of mercury, and that they predispose to adhesion formation through their irritative action. Iodoform and salol, they found, have very little irritating effect. Klotz[88] reported a decided falling off in the number of post-operative ileus cases following the substitution of aseptic for antiseptic technic. Thompson[58] found that sterile foreign bodies, such as gauze, cause adhesions in the peritoneal cavity, if large enough to cause irritation. Tinker[61] recognizes gauze drains and packs as common offenders in producing adhesions. Pankow,[62] in testing the relationship of denuded peritoneal surfaces to adhesion formation, was able to produce adhesions in only one-half of his cases by stripping the parietal peritoneum sufficiently deep to cause multiple punctiform hemorrhages. Franz found no adhesions following aseptic peritoneal defects. Sänger[63] concluded, from operations in which portions of the parietal peritoneum were resected, that one wound surface is sufficient to produce adhesions, which inevitably follow, and that it is not necessary for two such areas to lie together for their formation. Klotz[88] states that post-operative ileus develops if an epithelial-free bowel surface, either through direct or indirect misplacement, lies in contact with a wound surface; and that the formation of adhesions is favored by the presence of blood. Rissmann[64] concluded from experiments on cats, dogs, and

rabbits that many adhesions occur accidentally in experimental work which are not intended; he differentiates seroserous adhesions, which form without sepsis, chemical or mechanical irritation, from the dense union caused by local infection, possibly through chemical or mechanical irritation, and surely through apposition of the bared subperitoneal connective-tissue layer with the normal peritoneum. He considers that the first type are easily loosened, but that the latter remain much longer, their exact duration not being known. Neuhof and Wiener [40] found that under aseptic conditions the intact omentum always adheres to foreign bodies and to raw surfaces within its reach, whether parietal or visceral; that it always adheres by its free edge; that when resected it always adheres by the remaining intact edge; that a raw omental margin may adhere a certain length of time—possibly a week—after resection of the edge, and that such adhesions occur independently of peritoneal denudations or of foreign bodies; and that when infection is present not only the edge but the surface of the omentum becomes broadly attached by a thick exudate, even when the edge has been excised. Rubin's [89] exhaustive study of the function of the great omentum, already referred to, brought out some interesting factors involved in adhesion formation usually not mentioned in this connection. Thus he reminds us that the omentum possesses no spontaneous motility, and that its displacements are to be explained by: (*a*) intestinal peristalsis; (*b*) intra-abdominal tension; (*c*) static condition of the stomach, colon, and small bowel; and (*d*) its anatomical relationship to the gall-bladder and spleen. Further, that it possesses no demonstrable chemotaxis; the phenomena usually attributed to this property being in reality due to the presence of intraperitoneal fluid, gas in the large bowel, or the suction action of the diaphragm. And that its value in inflammatory conditions depends upon its power to form adhesions which isolate and render innocuous toxic products through absorption and elimination, or destroy them through the agency of its phagocytic elements. Ward [65] in his unusually clear and scholarly review summarizes his

views with reference to the etiology of peritoneal adhesions as follows: "We may lay down the statement that the formation of peritoneal adhesions after operation is directly proportional to the amount of sepsis, traumatism, dry air contact, loss of heat, and raw surface there is present." It is evident, therefore, that abundant experimental proof is available to support the generally accepted view that raw surfaces and other less severe injuries resulting from direct mechanical insult to the peritoneum furnish one of the commonest, if not the most frequent, causes of adhesions. In this connection, moreover, too much emphasis cannot be given to the importance of exercising the utmost care and gentleness in all intraperitoneal manipulations. Rough handling of the viscera; unintelligent, and I might say sometimes almost brutal, use of retractors and other instruments; mauling the bowel surface by the introduction of innumerable gauze pads, which, to be sure, add materially to the comfort of the operator, but more to the distress of the patient; the application of dry gauzes to the peritoneal surfaces, which generally adhere and when removed often bring away with them the surface endothelium; unnecessary sponging, as a sort of surgical tic or habit-spasm; careless application of hæmostats, with painful indifference to the mass of crushed tissue left to necrose in the grip of the ligature—all of these constitute transgressions of which few of us can claim innocence. But they also constitute a prolific source of adhesions, and should, therefore, be constantly borne in mind, in order to impress upon ourselves the value and importance of diligently cultivating a healthy aversion to unnecessary trauma, and a profound respect for the tissues.

In the beginning of this paper I ventured to predict that peritoneal adhesions will of necessity always remain an inevitable part of abdominal surgery. I wish here to call attention to the fact that the soundness of the reasoning adduced in support of this proposition has been clearly established through the cumulative evidence that has steadily accrued in support of it throughout the detailed discussion of this whole subject. I stated, further, that it will be found in the last analysis

that in the intelligent management of peritoneal adhesions, the abdominal surgeon has recourse to three classes of procedures, namely, (1) measures which prevent adhesions; (2) measures which restrict their formation to the harmless variety; and (3) measures which aid in their absorption. Now it will become apparent from the following consideration of the prevention and treatment of adhesions to which of these classes each procedure thus far suggested belongs.

In the first place, certain prophylactic measures at once suggest themselves as being clearly indicated from what has already been said. Briefly stated, these are: rigid asepsis; avoidance of mechanical, chemical, or thermic trauma; careful covering over of all denuded surfaces; use of moist hot gauze; avoiding exposure of the peritoneum to air. Thus far practically everyone is agreed. But the common experience that troublesome and dangerous adhesions still quite frequently occur, in spite of the strictest possible observance of these measures, has led investigators to undertake the most varied and elaborate researches with the hope of discovering some prophylactic or remedial agent that would prove efficacious in all cases. As I have already pointed out, this is a vain hope, and such efforts are fundamentally wrong. Nevertheless, this work has resulted in the production of many ingenious and valuable procedures, all of which have at one time or another been enthusiastically advocated, and have received varying degrees of support from the profession generally. The reports of these heterogeneous devices can be conveniently grouped and discussed as follows:

Non-absorbable Protective Membranes.—From time to time investigators have attempted to prevent adhesions to raw surfaces by covering them over with films of some foreign substance that would serve as a protective membrane and that could be kept in position until the endothelium had regenerated. Thus Stern,[66] in 1889, experimented with collodion for this purpose; he warmly recommended it for covering pedicle stumps, but otherwise was unsuccessful with it. Wright[67] used a gelatin-formalin coagulum; his technic was

to cover oozing surfaces with a 15 per cent.–20 per cent. solution of gelatin, to which 1 per cent.–2 per cent. formalin was added; this caused the gelatin to form a coagulum in a short time, and to become fixed to the raw surface. Its use has not met with general favor, however. Morris [68] claimed from his experiments on rabbits that he found aristol to be insoluble in serous fluids, and that when dusted over raw surfaces it quickly forms a protective covering, with the aid of the coagulated lymph, which cannot be brushed off. He strongly advocated this lymph-aristol coagulum as a valuable anti-adhesion measure. Ellis [69] tested this idea on dogs with a number of different substances, including silver-foil; formalin-gelatin mixture; solutions of gutta-percha in (*a*) chloroform, (*b*) carbon bisulphide, (*c*) xylol; and thin sheets of collodion, sterilized and hardened in bichloride of mercury. He reported failures with all of these substances, except the last, and regarded it as impracticable for use in the abdomen, because it cannot be held in position. It is very evident from the reports that none of these substances can be relied upon to furnish more than a small percentage of successful results, and, on this account, cannot be recommended for general use.

Manual and Postural Arrangement of the Viscera.—This is accomplished partly through proper disposal of the viscera with reference to normal anatomical relationship, at the end of the operation, and partly through post-operative posture in the ward, with the double idea of avoiding permanent kinks at those parts of the gastro-intestinal tract which are known to cause trouble, and for the further purpose of preventing contact with raw surfaces by gravitating the abdominal contents away from them. Tinker,[61] in a paper replete with practical suggestions, in addition to the commonly accepted procedures, emphasizes the thorough ante-operative evacuation of the bowels; post-operative posture to gravitate the abdominal contents away from raw surfaces for four or five days; avoidance of flatulence by stimulating peristalsis with strychnine and eserine; restricted and easily digested food; intestinal antiseptics; the importance of withholding mor-

phine; the employment of stupes and enemata; and getting patients out of bed early. Clark[70] reminds us, in a very forceful contribution, that certain anatomical considerations are of fundamental importance in connection with the problem of peritoneal adhesions. Thus he condemns the use of the omentum for the prevention of adhesions when it will thereby fix or drag down the stomach or transverse colon; because it causes gastric disturbance in the former event, and obstinate constipation in the latter. He further points out those movable parts of the gastro-intestinal canal that commonly produce untoward symptoms, if permanently kinked—especially the pylorus, duodenum, upper jejunum, pelvic loop of the ileum, cæcum, transverse colon, and sigmoid; and enjoins care in replacing the viscera in their proper relationship, especially where ptosis exists. Finally, he recommends the routine use of large enemata of hot salt solution at the end of abdominal operations, in order to fill the colon; which not only adjusts the latter properly, but further serves as an internal hot water bag applied directly to the sympathetic nervous system and great vessels, thus preventing shock, tympanites and adhesions, as well as stimulating the kidneys.

It seems to me that this idea of manual and postural arrangement of the viscera according to normal anatomical relationship is worthy of especial emphasis. Not only should it be employed as a routine measure, but it applies with particular fitness to that large group of cases in which we have no hope of successfully and completely preventing adhesions, and where, therefore, our choicest alternative is to restrict them to the harmless variety. Every surgeon is longing for some discovery that will dispel the dread and reluctance with which he approaches those miserable unfortunates, seen in every clinic, whose abdominal walls look like a patch-quilt from the scars of numerous laparotomies, who possess no vestige of endothelium on their parietal peritoneum, and whose viscera seem hopelessly entangled in an interminable meshwork of adhesions. We reluctantly add another scar; we painfully and aimlessly dissect in various directions from whatever

starting point our incision affords; and this we continue until the patient's collapse forces us to desist, when we gloomily close the abdomen, conscious of two things: namely, that we have not helped the patient, and that the same performance will, ere long, have to be repeated either by ourselves or some unfortunate colleague. Now would it not be wiser to study the situation a little more closely beforehand, especially from the anatomical stand-point to which Clark has drawn attention, and to determine clinically, if possible, which zone of adhesions is responsible for the chief trouble; then to assemble our most trustworthy methods, and to concentrate our operative attack upon an intelligent effort to restore normal anatomical relationship, and to restrict such adhesions as must of necessity follow to areas where they will either aid in the accomplishment of this purpose or else can do no harm?

Peristalsis.—Considerable work has been done on the early post-operative administration of various cathartics, with the idea of stimulating strong peristalsis, and thus liberating early adhesions as well as preventing their recurrence through constant motility of the bowel. Klotz[88] reports successful results in treating acute post-operative obstruction by gastric lavage with four to six quarts of warm salt solution, followed by the introduction of one and one-half to two ounces of castor oil through the stomach tube. He considers it useful only in obstruction from fresh adhesions. Cumston[71] recommends, in a clinical lecture on adhesions, the hypodermic administration of physostygmin for several days following laparotomy, with the idea of constantly changing the peritoneal surfaces in contact through peristalsis. Byford[72] and Paton[73] also recommend early catharsis with the same idea in view. Vogel[23] obtained a fair measure of success experimentally with physostygmin as an anti-adhesion measure. V. Hippel[74] considers this drug a valuable post-operative agent in preventing adhesions and ileus and recommends it highly. Busch and Bibergeil,[75] on the contrary, found experimentally that this drug is not efficacious in preventing adhesions. Uyeno[76] saw no effect on adhesions experimentally

produced in rabbits by irritants (iodine, and dilute acid, and alcohol) from the use of phyostygmin. But systematic massage effected degeneration and absorption of them in most cases, leaving the intestinal coils free from each other. Conflicting opinions appear to be held, therefore, with reference to the value of early stimulation of peristalsis as a prophylactic measure against adhesions. It seems to me that it can scarcely be recommended as a routine procedure, but that in properly selected cases, dependent upon a number of obvious considerations, it is of distinct value.

Specific Drugs.—Already some observers have attempted to deal with peritoneal adhesions through the specific action of certain drugs in the body. Eastman [77] recommends the administration of iodides, in the form of the syrup of hydriodic acid, claiming that it inhibits the proliferation of connective tissue and aids in the absorption of adhesions. Thiosinamine, and its combination with salicylate of sodium, known as fibrolysin, have been accredited with possessing a softening influence upon cicatrices, and other abnormal growths of connective tissue. Offergeld,[78] with a full review of the literature, reports only failures in the treatment of peritoneal adhesions with this drug, after giving it a thorough trial, with close observations, in 55 cases. Busch and Bibergeil [75] tried the introduction of fibrolysin dissolved in salt solution directly into the peritoneal cavity, but found that it was absorbed too rapidly to be of any noticeable value. Michael,[79] on the other hand, reports most favorable results in the treatment of two cases of perigastric adhesions with it. Sidorenko [80] has just reported the results of a clinical, experimental, and histological study of fibrolysin on cicatricial tissue. From a critical study of the results of other workers, and from his own results, he concludes that it does not exert any therapeutic effect upon cicatricial tissue. Hertzler [21] tried to diminish the coagulability of the blood, with the idea of preventing agglutination through the transformation of the exuded serum into fibrin—the first essential stage in adhesion formation. He used (*a*) phosphorus by mouth, because it destroys fibrinogen and thus

prevents coagulation; and (*b*) peptone hypodermically, because it neutralizes the fibrin ferment in the blood. He claims absolute success with phosphorus. Marvel [81] recommended introducing adrenalin into the peritoneal cavity in warm salt solution to prevent adhesions, claiming that it dissolves the peritoneal exudate and thus aids in its absorption; and further, that it prevents subsequent exudation by stimulating vasoconstriction and thus shutting off leakage. It appears, therefore, that an encouraging measure of success has attended these pioneer efforts to apply specific chemotherapy to the problem of peritoneal adhesions, and it seems to me that further development along this line is to be confidently expected, inasmuch as the possibilities of this important field of research are just beginning to be recognized and to attract wide-spread attention.

Normal Salt Solution.—Large quantities of physiological salt solution poured into the abdomen at the end of the operation in order to float the loops of bowel into their normal relationship and to keep denuded surfaces separated was at one time extensively used. Müller,[82] in 1886, was the first to recommend this measure, although Malcolm [83] independently advocated the same thing in 1890. Stern [66] concluded from his experiments that the formation of adhesions was not hindered by this procedure. Morris [68] came to the same conclusion, and explained the failure as being due to rapid absorption of the fluid. This view has since been abundantly corroborated, and there is no evidence to show that new growth of endothelium over raw surfaces occurs to any considerable extent before the fluid is absorbed and they are again in contact. Cumston [84] actively opposes its use not only for this reason, but also because he thinks this rapid repletion of the circulation is dangerous; that it causes the intestines to float in contact with raw surfaces; and that it pushes the diaphragm up, causing dyspnœa and pneumonia.

Gases.—Bainbridge [85] has recently advocated distending the abdomen with oxygen gas just prior to complete closure of the peritoneum, as a useful resuscitating and anti-adhesion

measure. Cleveland [86] suggests the employment of oxygen to inflate the intestines in order to prevent and relieve acute post-operative obstruction, with distention, vomiting, rapid pulse, and respiration. Quite recently also Gellhorn [87] has recommended with considerable enthusiasm the periodic induction of intra-abdominal hyperæmia by means of the local application of the hot-air bath to the lower trunk. Strumpel [88] reported last year quite a large series of major abdominal operations and hernias in which this measure was employed. It was applied for one and one-half hours, at three-hour intervals, during the first forty-eight hours, if necessary. He warmly recommends it as a part of the routine post-operative therapy, claiming that it stimulates early peristalsis, with the passage of flatus and fæces; that it improves the patient's condition; that it is a prophylactic measure against peritonitis and adhesions; and that where the former exists it aids in its cure and localization.

Eschar of the Thermocautery.—As already pointed out, if this measure is utilized, the cauterization should be very thorough, so as to produce a deep and lasting charring of the tissues. It undoubtedly possesses distinct advantages under certain conditions.

Lubricants.—Because of their harmlessness, ease of application, and apparent effectiveness in many cases, various oily and fatty substances are perhaps more extensively used than any other single artificial measure in the treatment of adhesions. A number of substances of this kind have been suggested from time to time and carefully studied experimentally. Morris [68] testifies that he saw Martin, of Berlin, in the eighties rubbing oil on raw peritoneal surfaces. He is generally accredited with being the first to employ this measure, although I have been unable to find any publication from him on the subject. Vogel [28] obtained some success in rabbits with a mucilage of gum arabic. Busch and Bibergeil [75] tested a number of substances—including lanolin, paraffin, olive oil, and agar—all of which irritated the peritoneum and favored adhesions; while gum arabic and gelatin were too rapidly absorbed

to be of value. Blake[89] concludes from a small number of experiments on cats that moderate quantities of olive oil (1–4 oz.) are not dangerous in the peritoneal cavities of animals; that it remains there 5–15 days; and that it tends to prevent adhesions to denuded or inflamed surfaces, but is not always effective. Gellhorn[87] experimented on dogs and rabbits, using liquid lanolin, but obtained only partial success. Claypool, Vance, Robertson, and Field[90] tested olive oil and liquid petrolatum on dogs. They concluded that the former tends to prevent adhesions, but that the latter is of little value. They found olive oil in the peritoneal cavity uniformly after three weeks in sufficient quantity to measure; sometimes also at the end of four weeks. They recommend sterilizing the olive oil at 115° C. for 15 minutes, which they think does not split off fatty acids that irritate the peritoneum. Wilkie[91] also calls attention to the fact that the irritation of olive and other oils is due to the separation of fatty acids in the process of sterilization. He recommends vaseline oil—a liquid paraffin which comes to the surface in the preparation of vaseline—as being absolutely neutral and unchanged by sterilization. He strongly advocates its use in mopping over denuded surfaces in the peritoneal cavity. This class of substances seems undoubtedly to possess some merit as prophylactic agents against adhesions; and it is very probable that the presence of fatty acids set free during sterilization is responsible for some of the conflicting results obtained. I have had opportunity, however, to observe the ultimate effect of both olive and vaseline oils in one case of very extensive peritoneal adhesions. After the adhesions were released, I carefully applied sterile olive oil to all of the denuded surfaces before closing the abdomen. At a subsequent laparotomy for pernicious vomiting, about a year later, the adhesions were fully as wide-spread and dense as at the other operation. This time I substituted vaseline oil, which was applied with great care and thoroughness; but again within a year laparotomy became necessary, and there was no evidence whatever of benefit from the lubricant. I am indebted to Dr. H. A. Kelly for

the privilege of mentioning this case, which was seen in his department at the Johns Hopkins Hospital.

Non-viable Animal Membranes.—The so-called Cargile membrane, made from the peritoneum of the ox, a similar membrane made from the shark's peritoneum, goldbeaters skin, derived from the outer coats of the cæcum of the ox, and a finely woven cloth made of catgut constitute the members of this group. Cargile membrane has been more extensively used than any of these, due largely to the enthusiastic advocation of it by Morris.[92] He obtained the idea from Dr. Chas. H. Cargile, of Bentonville, Ark., and hence gave the membrane his name. Morris concluded from a small number of experiments on rabbits that the membrane resists absorption in the peritoneal cavity more than 10 and less than 30 days; that it causes temporary loose adhesions of a harmless kind, which are mostly absorbed in less than 30 days; that it causes very little disturbance, is not a good culture medium, protects raw surfaces until repair occurs, and remains in position without stay-sutures, if kept dry. In a later publication he admits failure with the membrane in some cases. He suggested substituting shark's peritoneum, because it is cheap and plentiful. Baum[93] justly claims priority in the discovery of the so-called Cargile membrane. In 1894 he published a brief report of experiments with catgut woven into cloth, fish-bladder, and peritoneum prepared from young calves freshly slaughtered. His results were encouraging, and he warmly recommended these substances for general use. Craig and Ellis[94] subjected the Baum (Cargile) membrane to a careful experimental and histological study. They showed that in the peritoneal cavity, both the chromicized and unchromicized varieties are of no value in preventing adhesions, but that, on the contrary, they act as foreign bodies, and promote adhesion formation. Stavely[95] reports a case laparotomized six times for adhesions, three of which operations he performed. He employed this membrane, but found at a subsequent laparotomy that it had failed. Lauenstein[96] used a silk protective to prevent adhesions about the gall-bladder in one case, but found it of no

practical value. Theoretically, it is surprising that these membranes do not uniformly provoke rather than prevent adhesions—and, as shown by the above citations, there is considerable evidence in support of this view—inasmuch as a piece of dead animal tissue that has been kept in preservative fluid, although it may later undergo absorption, is nothing more nor less than a true foreign body while it remains in the peritoneal cavity, and must be so regarded in its relations to adhesion formation. It seems to me inevitable, therefore, that these substances will gradually fall into disuse.

Viable Grafts.—Much more rational are the efforts to cover raw surfaces by plastic operations on the peritoneum, or with peritoneal or omental grafts, as will appear from the following reports. Senn [99] demonstrated experimentally, in 1888, that omental grafts 1–2 inches wide, and long enough to completely encircle the bowel, retain their vitality, become firmly adherent in 12–18 hours, and freely supplied with blood-vessels in 18–48 hours. Also that both the adhesions and the vascularization are hastened and improved by preliminary scarification of the serous surface and the graft. He recommended the use of such grafts in wounds of the gastro-intestinal canal, to reinforce circular enterorrhaphy, and to cover up peritoneal defects and pedicle stumps. V. Dembowski [59] the same year reported experiments which showed that if the omentum be sutured to the anterior abdominal wall, it becomes firmly adherent in 3–4 days, but that the intestine never adheres to it. Tietze [98] reported successful reinforcement experimentally of stomach and intestinal sutures by the application of parts of the attached omentum. His cases included three groups: (1) reinforcing experimentally produced necrotic areas in the stomach and intestinal walls; (2) reinforcing end-to-end intestinal anastomosis; (3) closure of stomach defects with plugs of omentum. Thompson [58] concluded that if the omentum be simply spread out behind the abdominal wound, it prevents the intestines becoming adherent to the latter. Webster [44] recommends, among other measures, covering raw surfaces with adjacent healthy peritoneum, and

also transplanting grafts of both peritoneum and omentum. Amann [99] advocates covering defects in the pelvis with movable peritoneal flaps, such as can be obtained from the anterior half of the pelvis. He also recommends mobilizing the sigmoid and suturing it to the uterus, or, if the latter is removed, to the bladder peritoneum, or to that of the pelvic brim, to prevent the small bowel falling into the pelvis and becoming adherent. Morris [92] also employs the Senn omental graft. Loewy,[100] on the basis of his experimental work, recommends the employment of omental grafts in a number of conditions, and discusses several types that he has successfully used. Girgolaff [101] recently carried out an interesting series of experiments on omental grafts in cats and dogs, successfully covering raw surfaces of the large bowel, bladder, and stomach, without adhesions to the graft and without failure of the latter. On the small bowel, however, the graft adhered either to adjacent loops of small bowel or to other structures. He injected the thoracic aorta 18–24–48 hours, and 3–5–7 and more days after the grafting with coloring matter, and even where the graft had formed no adhesions, except to the organ applied, he succeeded in thus injecting its capillaries in the surprisingly short period of 24 hours, and to a greater extent later on. Springer [102] published last year the results of a careful experimental study of omental grafts in dogs. He found that if the entire free omentum be amputated and simply dropped into the abdomen, it does not necrose but becomes spread out, adheres to the parietal peritoneum, and becomes quickly vascularized. Further, that detached omental flaps sewed over considerable areas of the small bowel adhere, are rapidly vascularized, and are useful for covering raw surfaces without causing any narrowing of the lumen. But that such flaps always adhere extensively to neighboring loops of bowel; they do not compensate defects, but reinforce; they do not prevent adhesions, except on movable organs with strong peristalsis, like the stomach and urinary bladder; that they are good for reinforcing lateral and end-to-end anastomoses of hollow viscera; that omental stumps also become

adherent unless covered in, and that omental grafts may be used to cover peritoneal defects.

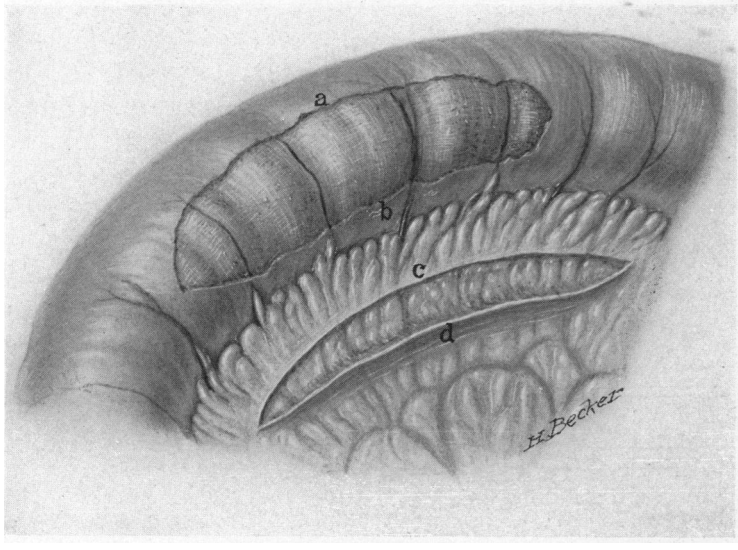
It is very evident, therefore, that grafts of fresh omentum and peritoneum have a very important and wide field of application in abdominal surgery, and that they constitute one of our most valuable prophylactic and controlling methods in dealing with adhesions. Autoplastic grafts are to be preferred, of course, but I am of the opinion that, with the exercise of proper precautions, homoplastic grafts might also often be advantageously used, at least in our larger clinics where abundant material is available. But the supply to be obtained even here would prove entirely insufficient for use in a case of generalized or universal peritoneal adhesions. These are the cases that baffle us, and that stubbornly resist any or all of the methods of treatment thus far suggested. I have already indicated the futility of repeatedly releasing these adhesions indiscriminately and in whatever direction seems to be easiest at the time of the operation, thus blindly dissecting without definite aim until the patient's collapse forbids our going further; and I pointed out, on the other hand, the wisdom of studying these cases more closely beforehand to determine clinically which area of adhesions are specifically responsible for the patient's symptoms. In the solution of this problem we will be greatly aided by bearing in mind especially those parts of the gastro-intestinal canal which are known to cause trouble when they become involved in adhesions and kinked. In the majority of instances one or more of these regions will be found to be our vantage point in the operative attack, and our effort should be to restore as near to normal as possible these parts. The method of procedure, then, is first of all an accurate diagnosis; next release the adhesions that are causing the trouble; then partly prevent and partly restrict their re-formation to the harmless variety by the judicious application of viable grafts of omentum or peritoneum—preferably autoplastic or homoplastic ones, but if these are not obtainable, use heteroplastic grafts of peritoneum, obtained from a freshly slaughtered calf under aseptic conditions just

prior to the operation, and carefully guarded from mechanical or chemical trauma—and by disposal and fixation, by suture if necessary, of the viscera according to normal anatomical relationship; so that whatever adhesions recur will aid in the accomplishment of our purpose. Such a course at least possesses the merits of being intelligent and feasible, and of saving the patient the added shock of a prolonged dissection through many square centimetres of viscerovisceral adhesions which are doing no harm, and which promptly re-form. These merits, to my mind, are sufficient to justify its adoption.

A NEW METHOD OF TREATING DENUDED BOWEL SURFACES.

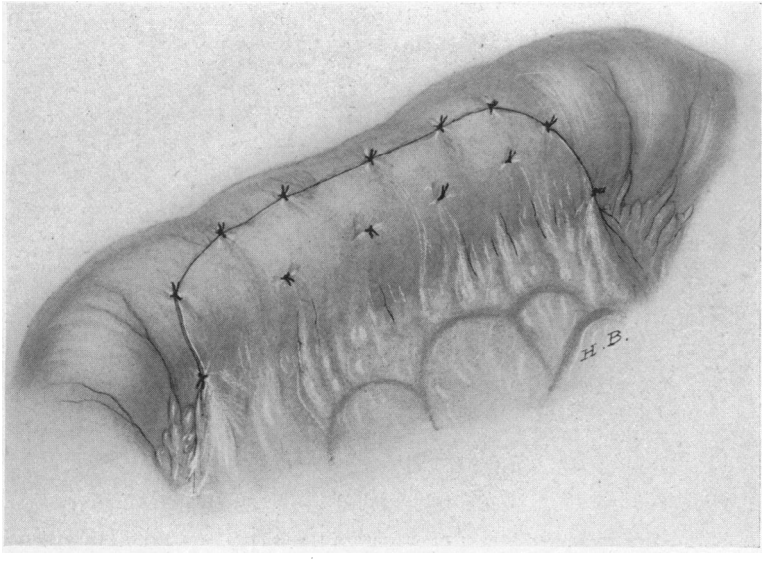
A few months ago, during the course of an operation for the relief of an enormous post-operative ventral hernia, a situation arose which suggested to me a new, and what I believed to be an eminently satisfactory, method of dealing with denuded bowel surfaces under certain conditions. The patient was a very large, fat woman, well past middle life, who by reason of circulatory and renal disease was rather a poor surgical risk. Moreover, about six months previously she had undergone a very serious operation for radical removal of the generative organs on account of a moderately advanced cancer of the uterine cervix, at which time the abdominal wound had evidently become infected and broken down, with a resulting hernia. Occupying the hernial sac, besides a bulky omentum densely adherent throughout, there was a long loop of ileum, coiled in a horse-shoe fashion, each limb of which had become so intimately adherent to the peritoneal lining of the sac as to render separation along any definite line of cleavage impossible. The two limbs were also adherent to each other by several transverse bands of dense fibrous tissue. After effecting the release of the intestine I had, therefore, two extensive raw areas, each measuring two to three inches in length, involving nearly one-half the circumference of the bowel, and separated from each other by six or eight inches of practically normal intestine.

FIG. 1.



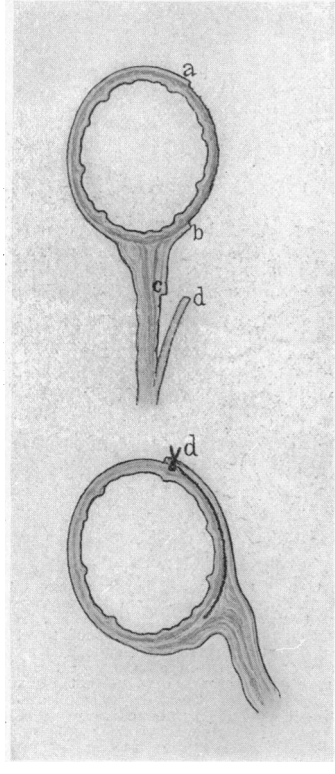
An extensive denuded area on the surface of the ileum is here shown. Observe that at its widest portion, *a–b*, it involves nearly half the circumference of the bowel. The liberal deposit of fat in the mesentery here represented admits of the ready separation of its two peritoneal leaves. Note that the incision for this purpose through the upper leaf is made about 1 cm. from its bowel attachment, in order to avoid the numerous branching vessels in this region. The separation of the flap *d* is now easily and safely effected to any desired extent, since the average width of the mesentery is eight inches. A flat, blunt instrument—a spatula, for example—is best suited for this step. The rich vascular anastomosis between the mesenteric leaves, afforded by the superimposed colonnade arrangement of the trunk vessels, is easily seen.

FIG. 2.



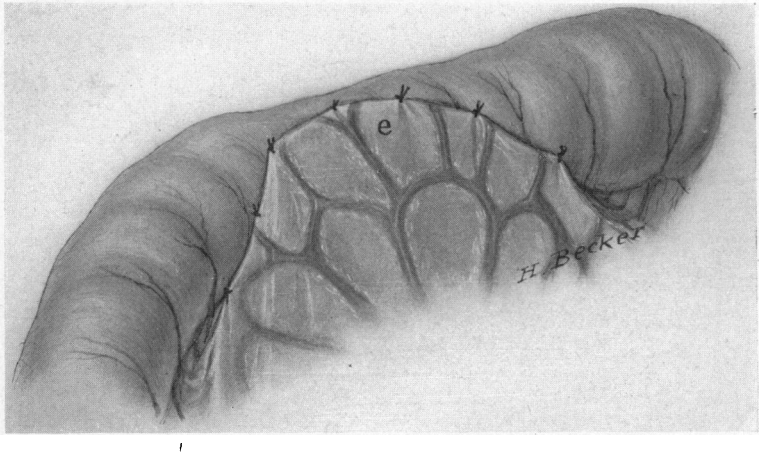
The detached flap of peritoneum is here shown drawn up over the raw bowel surface and firmly fixed by interrupted sutures of fine silk. Note how completely and satisfactorily the defect has been remedied. Observe too, that, owing to the mobility of both the bowel and its mesentery, the mechanical effect on the bowel lumen and the mesenteric circulation is negligible and cannot produce any serious consequences. Care must be taken to close the angles of the mesenteric flap just at the bowel margin as shown, to avoid the possibility of an intramesenteric hernia.

FIG. 3.



The bowel and its mesentery are here represented in cross-section. In the upper drawing, the area between *a* and *b* is the raw surface; *c* marks the point of incision through one peritoneal leaf of the mesentery; and *d* the flap to be freed and drawn up. The lower drawing shows the flap *d* closely applied over the denuded area, and fixed by sutures which should penetrate the submucosa.

FIG. 4.



The plication modification of the method is here shown. Owing to an almost total absence of fat between the peritoneal leaves of the mesentery in some cases, it is unsafe and impracticable to attempt their separation. In such cases *neither leaf is incised or separated from its bowel attachment*, but both leaves are grasped together at the proper distance from the bowel border, lifted over the raw surface, and fixed by silk sutures. It amounts to a plication of the mesentery or a partial envelopment of the bowel within both layers of its mesentery. Note that care has been taken to place the sutures between the vascular trunks. This simple modification renders the method applicable to all cases, is even more quickly executed, and is eminently safe and satisfactory.

Another factor of great surgical importance was the extensive dissection necessary to cure the hernia, by reason of the wide separation of the recti muscles, the enormous size of the opening, the abundant scar tissue produced by the old infection, and the atrophy and impaired vascularity of the tissues to be utilized in effecting the closure. These unfortunate circumstances, together with the patient's general condition, made it highly important that all possibility of wound infection should be scrupulously avoided, as well as that every possible precaution should be taken against the occurrence of intestinal obstruction, which might necessitate the undoing of all my work.

Now recalling the condition of the bowel surface just described, it is evident, upon consideration, that none of the customary methods of dealing with this complication were applicable to the conditions in hand. I could not, for example, invert the raw surfaces, because of their extent and proximity to each other—obstruction would almost certainly have ensued. The various other methods already described were either impracticable or too unreliable, in view of the serious consequences of failure. I did not dare resort to lateral anastomosis, because I was dealing with the lower ileum; and while this procedure would have taken care of the raw surfaces and obviated the danger of obstruction, it would at the same time have afforded an excellent opportunity for infection of the devitalized tissues of the wound, with complete destruction of all my plastic work and immediate recurrence of the hernia. Fortunately, the problem was practically solved for me by the accidental laceration and partial retraction of one leaflet of the mesenteric peritoneum just along the line of its attachment to the bowel, and adjacent to one of the raw areas on the surface of the latter, which occurred during its separation from the hernial sac (Fig. 1). There being a considerable deposit of fat between the two layers of mesenteric peritoneum, it was a surprisingly simple and easy procedure to extend the separation of the torn leaflet and its attached fat in all directions from the underlying vessels and the oppo-

site intact leaflet with its fat, thus obtaining a large, movable flap of normal peritoneum, which was easily drawn up without tension, spread out over the raw surface on the bowel, and tacked down with a few fine silk sutures (Fig. 2). The result was eminently satisfactory in every way, this very simple device, which was quickly carried out, having sufficed to abolish a rather complex and embarrassing surgical situation. The patient's recovery was complete, and she is now comfortable and happy.

This fortunate experience led me to investigate the idea further, in order to determine accurately its possibilities and limitations, and to meet certain theoretical objections.

Thus it was desirable to ascertain if the method could be applied to all portions of the intestinal tract; if the separation of the two peritoneal leaves of the mesentery could be rapidly effected, without injury to the vessels, in poorly nourished individuals whose mesentery usually contains very little fat; and if not, to consider the feasibility of lifting a fold of both leaves of the mesentery, without incising either, over the raw surfaces, thus effecting practically a plication of the mesentery—a modification of the method that would make it applicable to these cases also (Fig. 4); to determine further, what effect this axial rotation or partial envelopment of the bowel within its own mesentery would have on the calibre and direction of the lumen, with reference to obstruction; to investigate to what extent it would be practicable to so treat the bowel; to ascertain particularly what effect was produced on the mesenteric and bowel circulation by this mechanical alteration of normal conditions; and finally, how much tension the leaflet of peritoneum is capable of withstanding, with reference to its being torn loose by post-operative distention or vigorous peristalsis.

The fresh cadaver seemed to offer the best method of settling these questions, and my conclusions, based upon such a study, are as follows:

1. The procedure is best applicable to that portion of the intestinal tract where, in such cases as the one described,

present methods are inadequate, namely, from the upper jejunum to the lower ileum. It may be rationally applied, however, to any portion of the bowel possessing a mesentery of sufficient length to admit of its ready execution.

2. Care must be exercised at the duodenum, upper jejunum, and lower ileum not to produce kinks of the bowel.

3. In cases exhibiting a scanty deposit of fat in the mesentery, plication is a rapid, safe, and efficient substitute for separation of the two peritoneal leaves.

4. Aside from a slight spiral rotation, which in view of peristalsis and the mobility of the parts is entirely insufficient to produce obstruction, the procedure has no demonstrable effect on the bowel lumen.

5. It can be safely extended to include nearly one-half the circumference of the bowel, and three to four inches in continuity. There is no apparent reason why it should not be repeated as often as necessary at different levels of the intestinal tract.

6. In view of the rich vascular anastomosis and the mobility of both the bowel and its mesentery, if care be exercised in placing the sutures so as to avoid the trunk vessels, the effect upon the circulation is negligible.

7. Stability and permanence of the coaptation is readily secured through intelligent disposition of the sutures.

SUMMARY.

Peritoneal adhesions are of two kinds, those which are useful, and those which are harmful and dangerous.

It is futile to search for some agent that will banish adhesions from the realm of abdominal surgery, inasmuch as the processes involved in their formation are identical with those involved in peritoneal repair.

In dealing with peritoneal adhesions, the surgeon has recourse to three classes of procedures: (1) measures which prevent their formation; (2) measures which restrict their formation to the harmless variety; (3) measures which aid in their absorption.

Certain anatomical and physiological characteristics of the peritoneum have an important bearing on the problem of peritoneal adhesions; notably its extensive area, its remarkable absorptive power and ability to successfully cope with infection, the variable sensibility of different portions, the continuity of its endothelial surface, the rapidity with which it can form adhesions, and the completeness with which it can later absorb them.

Injury or death of the highly vulnerable surface endothelium is sufficient to set in motion the chain of pathological events which may terminate in dense adhesions.

Etiologically, there are a number and variety of factors involved, but they can all be grouped under the two heads—sepsis and trauma.

As specific prophylactic and curative measures, emphasis should be given to: (1) rigid asepsis; (2) the use of moist hot gauze; (3) careful covering of all raw surfaces; (4) avoiding unnecessary exposure; (5) restricting trauma; (6) gastro-enterostomy and entero-enterostomy; (7) returning the viscera to their proper anatomical relationship; (8) spreading out the omentum over the visceral surfaces before closing the abdomen; (9) careful closure of the peritoneum. A number of additional safeguards are available which have been tested and proven to be of value under certain conditions. The most reliable of these for general use are: (1) viable grafts of omentum or peritoneum; (2) lubricants; (3) judicious ante- and post-operative therapy—especially with reference to posture, catharsis, enemata, and length of stay in bed.

The field of specific chemotherapy offers the brightest hope for future progress.

Success in the management of the more aggravated adhesion case depends largely upon accurate clinical diagnosis, followed by intelligent operative procedures, as pointed out.

In properly selected cases, the use of adjacent mesentery for covering raw bowel surfaces possesses distinct advantages over all methods hitherto proposed.

In conclusion, I desire to express my thanks to the Pathological Department of the Johns Hopkins Hospital for giving me the privilege of testing on the fresh cadaver the method above described.

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