which must depend on the condition of the organ. The penis is then firmly tied; nothing is better than an indiarubber tube for the purpose. Then a pear-shaped bag of indiarubber, tolerably stout, so as to retain that form, and capable of holding at least sixteen ounces of fluid, is folded longitudinally and introduced into the rectum. By the tube which forms its apex, and is supplied with a stopcock, water is forced in so as fully to distend the bag *in situ*. The outline of the bladder will now be traced above the pubic symphysis. The usual vertical incision is made, and dissection carried down to the bladder, with the usual precautions with which we are familiar. The ease and the certainty, however, which are ensured by the firm position of the bladder in this system, render it much superior to the old one. I have operated by the high operation twice only, and that before the introduction of the new method. Since that time I have met with no case which I have not been able to deal with satisfactorily by lithotripsy at a single sitting, of which several examples are placed before you—the calculi weighing from one to nearly three ounces. The next case which offers for which the knife is required, I shall almost certainly submit to the high operation, with Petersen's modification. And the only reason why I have not yet performed it is that I have easily and successfully employed lithotripsy in cases precisely similar to those for which the French surgeons are at present adopting Petersen's procedure.

Lecture

ON THE

PRINCIPLES WHICH UNDERLIE THE

CONSTRUCTION OF APPLIANCES FOR THE REMOVAL OF SICK AND WOUNDED.

BY ROBERT LAWSON,

INSPECTOR-GENERAL OF HOSPITALS, LATE PRESIDENT OF THE
EPIDEMIOLOGICAL SOCIETY, FELLOW OF THE
STATISTICAL SOCIETY.

AT the request of the Committee of the Volunteer Medical Association I have undertaken to give a lecture on some subject within the range of those on which it is the object of their organisation to diffuse information; and it appears to me I cannot meet their wishes more advantageously, at the present time, than by pointing out the principles which underlie the construction of the appliances recommended for the removal of the wounded from the field of battle. Such appliances are of great use in moving sick and wounded elsewhere; but inasmuch as the transport of individuals who have sustained severe injuries in action is their most prominent and important employment, all their details require to be arranged with especial regard to the requirements of this service. Military operations in which this country is engaged are usually carried on at some point with which our communications are by sea; this requires that our transport vehicles should be constructed so as to permit of their being taken to pieces, and packed in the most compact form for stowage on board ship.

The first service to be rendered to a man disabled in action is to remove him to a position out of fire, where his injuries may be examined and the requisite treatment applied, to enable him to be sent on to the hospital where it is intended he should be retained for cure. To facilitate this a great variety of appliances have been recommended at various times, and employed more or less, as the materials for their construction were available. These are now pretty generally displaced by the field stretcher.

Field Stretcher.

A field stretcher is essentially a hand litter, with the assistance of which two bearers can remove a wounded man, with the least exertion on their own part, and with the least injury to the patient, and it will approach perfection in proportion as it realises these ends. The stretcher usually consists of two side poles, to which a canvas or net bottom is attached on which the patient is laid, and there are cross

pieces of wood or metal to prevent the poles coming together when raised from the ground. Legs or feet are frequently added, to keep the bottom off the ground when a sick or wounded man is on it. These elements have been combined in a great variety of ways, according to the views of individual constructors, some of which have proved pretty successful, while others can be considered little better than failures.

To obtain a clear idea of what is required in a field stretcher, it is necessary to analyse the motions of the bearers while carrying it. While they are standing still, with their feet together, a perpendicular line passing through the centre of gravity of their bodies will touch the ground between their feet, but, as soon as they begin to move, they must bend their bodies to that side on which a foot touches the ground so as to bring their centre of gravity over the point of support, and thus maintain their equilibrium; the effect of this is to cause a motion swaying from side to side with each pace of the bearers, which might prove beneficial if not counteracted; by making the bearers walk out of step, however, the sway of one to the right is neutralised to a very large extent by the simultaneous sway of the other to the left, and the individual carried is but little affected.

There is another motion, which is in a vertical direction, which requires a different mode of treatment. Let there be two bearers, 5 ft. 8 in. in height, carrying a stretcher; when standing, with their feet together, the perpendicular from the centre of gravity of the body of each to the ground will pass through his hip-joints, and the distance of the centre of motion in these to the ground will be 34 in. If now one foot be advanced 30 in. (the usual military pace) and placed on the ground, while the other remains in its original position, the distance from each hip-joint to the point of support of each foot will remain 34 in., but the perpendicular from the joint to the ground will be 30½ in. only, or 3½ in. less than when the feet were together; so that the body of a man about the height mentioned, with anything he may be carrying, is raised and falls again 3½ inches every pace he takes, when these are 30 in. in length. With paces of 20 in. long the perpendicular from the hip-joint to the ground in the middle of the pace is 32½ in., so that the rise and fall is 1½ in. only, instead of 3½ in. with the longer step. Surgeon-General Longmore, in his Treatise on the Transport of Sick and Wounded Troops, at p. 171, gives some actual measurements, which coincide exactly with those arrived at above from calculation, when there was no one on the stretcher, but with a man carried they were with each length of step three-quarters of an inch more. He proceeds, "Of course, in marching at either pace there is an alternate rise and fall to the same extent, and the effect of this on the elastic poles of a stretcher can be readily imagined."

A stretcher with light side poles, such as circular poles of 1½ in. in diameter, even with the most careful walking will bend much more than the distances given above as due to the motions of the bearers; the effect on the person carried is a vertical oscillation greatest over the lower part of the chest, the abdomen, and thighs, less towards the head and feet, and repeated at every step. Serious cases of ordinary sickness would be much incommoded if subjected to such a trial, but for men with severe wounds in the trunk or fractured thighs it would be little short of torture. As regards the bearers, the descent of the stretcher from its highest point, with the body of the person upon it, is to be regarded as a body falling under the action of gravity, and every inch it proceeds beyond that due to their movements in walking generates an additional force acting downwards, which might be avoided, but which they have to meet by additional exertion of the arms, shoulders, and trunk. To give a quantitative illustration of this, let it be assumed that a stretcher with a wounded man upon it weighs 150 lb., and that the vertical oscillation due to the motion of the bearers amounts to 4 in., but, that owing to the yielding of the side poles the mean fall of the body is 2 in. more, the additional force generated is equal to that required to raise 150 lb. 2 in. in the same period of time, or its equivalent to raise 10 lb. 30 in., or 2½ ft. This is the force produced by the fall, but inasmuch as the body has to be raised 2 in. again, the actual force thrown on the bearers is that required to raise 150 lb. 4 in., or 10 lb. 5 ft. If, now, by adding 10 lb. more material to the side poles, they were sufficiently stiffened not to yield the additional 2 in. above mentioned, the extra work thrown on the bearers would be to raise this weight 4 in. only, which is rather less than one-fifteenth of the extra work thrown on them by the yielding of the weaker poles.

There was a considerable display of ambulance and field hospital equipment at the Paris Exhibition in 1867, and in 1868 a committee (of which I was a member) was appointed in this country to examine into the condition of the British equipment, and to suggest improvements. The field stretcher then in use had round side poles of ash, 8 ft. long and 1½ in. in diameter; it weighed 15 lb. The objections to it were the great amount of vertical oscillation inseparable from its use, and the want of any means of keeping it off the ground while the bearers were resting, or assisting the wounded man in their charge.

A stretcher which had been adopted by the French army authorities shortly before was placed in the hands of the Committee. This had side poles of ash, square in transverse section, with an area very close on 3 square inches, and of the same thickness throughout, except where reduced at the ends for the bearers to grasp. It weighed 20 lb., and in the extensive trials of it at Aldershot, under my own observation, it was found remarkably free from vertical oscillation, and was characterised by the men employed as bearers as being the easiest to carry of all those they had practised with, though none among them seemed aware of the principle on which this depended. The great stiffness of the stretcher was due to the large sectional area of the side poles combined with their small length, while the weight (only 20 lb.) was not such as to lead to any strong desire to reduce it. The objections to it were that the length (about 5 ft. 8 in.) was too small for many men, and there were at least three separate pieces, the absence of any of which would render it useless, or nearly so.

In designing a stretcher for the British army, the committee were actuated by the following considerations:—(1) That the sacking should be six feet in length; (2) that the stretcher should have as much stiffness as was compatible with moderate weight; (3) that the sacking should be raised from the ground by feet; (4) that the side poles should be capable of being brought together, the feet doubled up, and the whole packed compactly; (5) that every part of the stretcher should be so fixed that it could not be separated or lost. To carry out these objects, the side poles of ash were made square, with the corners above slightly rounded off, with the sides 1½ in. at the middle, with a transverse section of 3 square in., and to save weight tapering down to 1½ in., or 2½ square in. section, at the ends of the canvas, beyond which they were rounded off for the bearer to grasp. Steel traverses, hinged in the centre, and to the poles at the ends, permitted of the poles being brought together or extended as required; and steel feet, hinged so as to close in one direction, but to stand open against a check-piece when extended, completed the arrangement. The stretcher so completed weighed 25½ lb., it afforded a steady bed, though not quite so much so as the French stretcher, and possessed advantages which that did not. On reconsidering the matter, subsequent to the committee making their report, it appeared to me it would have been better to have made the poles of the same dimensions up to the ends of the sacking as they were in the centre; this would have added about 2 lb. to the weight of the stretcher, but would have secured practically as much stiffness as in the French stretcher, and would at the same time have relieved the bearers. This alteration has since been made, and a truck added in place of the steel feet. Stretchers so fitted are now to be seen in the Health Exhibition, and weigh 27 lb.

In the above remarks there has been very little notice of pillows for the stretchers, or slings for the bearers; the committee, however, considered both points fully. As regards pillows, they considered these were unnecessary for the field, inasmuch as every soldier has his great-coat or blanket and valise with him, and if wounded these would have to be carried to the rear with him; either of them can be employed to raise his head as desired, and under such circumstances a pillow, which would add to the weight and bulk and be of little real service, had better be dispensed with. As to slings, these are of two descriptions: that issued to our bearers is a simple leather strap, the middle of which is placed over the back of the neck, and the ends hang down over the upper part of the chest in front, while there are loops at the lower part into which the handles of the stretcher are inserted for carriage. This arrangement, it will be perceived, combines a vertical pull over the front of the chest with a forward pull of the neck, the latter having to be met by a corresponding exertion of the long muscles of the back to retain the head and neck in their proper position, in addition to their doing their portion of the work

of steadying the trunk under the vertical pull. Now, this additional exertion simply exhausts the bearer more rapidly than he would be if the forces he has to meet were differently disposed. This can be effected readily by employing what is called the yoke system of sling, which consists of two leather straps, the ends of each of which are fastened together, forming a sort of loop; these are placed one on each shoulder, and the poles of the stretcher are put into the bight of the loops below; a cross piece fixed to each loop just behind the shoulders prevents them slipping off, without causing any drag on the neck at all. The committee recommended that these, and these only, should be issued for use by the stretcher bearers.

Ambulance Waggons.

With ambulance waggons, as with stretchers, mere weight affords but a vague means of ascertaining their relative merits; alterations introduced with a view to improvement often turn out the reverse; and even high commendations by reputed authorities may prove an unsafe basis for an exact estimate of their qualities and of their fitness for rough service in the field. At the Paris Exhibition of 1867 thirteen full-sized ambulance waggons, besides four models, were brought together, including those of the French, English, and American Governments, and prizes were offered to inventors who, after a study of these patterns, and with the permission to adopt any valuable feature they displayed, should construct waggons better fitted for the transport of wounded. Two competitors were successful. Locati of Turin, who produced a waggon embodying some recommendations by Baron Mundy; and Dr. Evans of Paris, who had what was considered an improved form of the Rucker waggon, which had been employed in the United States. On the appointment of the Ambulance Committee in 1868 they applied to have specimens of these waggons placed at their disposal for thorough examination and trial, and at the end of the year they were delivered at Aldershot. Locati's waggon weighed 17 cwt. 2 qr., and had wheels of 33½ and 45½ in., with 1½ in. tyres. Evans's weighed 17 cwt. 1 qr., with wheels of 35½ and 52½ in., with 1½ in. tyres. The heaviest English waggon in the service at the time weighed 16 cwt. 2 qr. 21 lb.; it was equirota, wheels 50 in., with 3 in. tyres; its draught was consequently much lighter and much more suited for active service than either of the prize carriages.

In both of the Paris prize waggons it was proposed to carry two persons recumbent in the body, or eight sitting; an average man with his clothing and accoutrements weighs about 150 lb., or rather more than 1¼ cwt., and with these numbers the load on the hind springs would vary from 2½ to 10 cwt., in addition to that of the body of the carriage. Now, springs which would act properly with the smaller load would be quite unequal to sustain the greater one; and, *vice versa*, springs suitable for the greater would act so violently with the lesser ones as to be most injurious to serious cases, as anyone who has travelled over roughish roads in a vehicle with springs insufficiently loaded must have found out. It is usual in this country to meet this difficulty by having a check spring, which comes into action only after the ordinary springs have received their full load, and within certain limits this arrangement is applicable to ambulance waggons, but it is very doubtful whether, even with the check spring, loads varying so much could be carried satisfactorily. Neither Locati's nor Evans's waggon had check springs; and the springs of the former were found so weak at Aldershot that they had to be replaced by a stronger set, and soon after this, with full loads, the body of the waggon settled so much that it bore on the hind wheels, and ultimately tore the spokes out of the naves.

All these waggons, both British and foreign, were fitted with special stretchers, so that a wounded man had to be removed from that on which he was brought to them and transferred to the stretcher belonging to the vehicle itself. It was obviously for the advantage of the wounded that this change should be avoided, and to meet it the Germans had had their ambulance waggons built to receive their ordinary field stretcher—an example followed by the Ambulance Committee in this country. The ordinary track of our military vehicle is 5 ft. 2 in., and with this width the committee found they could have a serviceable waggon with a clear inside breadth of 4 ft. 2 in., which admitted two of the field stretchers, each 1 ft. 11 in. wide, and left space for a partition of 1 in. thick between them, which was carried up sufficiently high to prevent the occupant of one rolling over

or incommoding his neighbour from any unusual motion of the waggon.

The object of an ambulance waggon is to transport men who have sustained severe injuries with the least risk or inconvenience; and to effect this they must be subjected to the smallest amount of motion attainable, and in the least hurtful directions. When the springs of both sides of the waggon act equally, at the same time and in the same direction, a vertical motion only results. When the springs of one side only are put in action, they react on the mass above them, causing a heave upwards of that side, with a tendency of the body of the waggon to rotate round a line passing through its centre of gravity longitudinally, and compressing the springs on the opposite side. At the level of the floor this causes a vertical rising motion on the one side and a falling one at the opposite side, while at a variable point between them there is none; at some distance above the floor the vertical component is reduced, and a lateral motion becomes developed largely. In practice, of course, the two modes of action of the springs here mentioned are combined more or less, and varied to infinity by the varying obstacles the wheels encounter, but the motions resulting therefrom are all resolvable into the vertical and lateral components noticed above. If, now, the action of these motions on a person lying on a stretcher be considered, it will be seen that while either rising or falling every part of his body is borne on the stretcher, and all that it is possible to do is to render the transition from either to a state of rest, or to the opposite direction, as soft and gentle as possible by carefully adapting the springs to the load they have to carry. With lateral motions everything is different; there is no support anywhere, and even when the heave is not sufficient to throw the patient to one side of, or even off the stretcher altogether, it causes a rolling motion of the most injurious description for men with serious wounds or fractures; the body rolls from side to side on the chest, and the pelvis and lower extremities follow in the same direction, but at such an interval that the chest has nearly completed its oscillation in the opposite direction before the legs and feet have reached their full swing in the original one. During the Civil War in America, though some of the ambulance waggons were fitted for carrying two tiers of stretchers, the use of the second tier was virtually abandoned.

Locati and Evans introduced springs inside their waggons for the stretchers to rest on, with a view of easing the motion for their occupants, and many others have followed the same practice. All, however, seem to have overlooked the fact that springs, like musical strings, have periods of vibration, varying with their length and thickness, and that to place shorter and lighter springs inside a waggon to lessen the jar of those outside, was, at the same time, to place there a source of movement not in unison with the external springs, and one which this very want of unison could not fail to call into vigorous and, in the case of wounded men or serious medical cases, most injurious action. The committee tried, in the same waggon and at the same time, two stretchers in every respect similar, save that one was fitted with springs while the other was without them, and the difference as regards steadiness in favour of the latter was most marked. From all these considerations it is obvious that a man severely wounded is most advantageously situated where he is subjected to the motion of the body of the waggon alone, at a point as near the floor as can be managed, and the ease of this motion can only be adequately provided for by careful adaptation of the springs to the weight they have to carry.

As already stated, in both Locati's and Evans's waggons, when there were no recumbent cases, men sitting were intended to be carried, but the arrangements for those were far from satisfactory. An ordinary sized man, with a seat of 1 ft. 6 in. in height, requires a space of about 2 ft. 9 in. from his back forwards for the limbs; and if he have to sit for any length of time, it is advisable this should be extended to 3 ft., to admit of greater change of position to relieve the irksome feeling caused by retaining the muscles too long in the same state of tension. If the height of the seat be reduced, it can be made comfortable only by inclining the back, and extending the legs, or, in other words, increasing the horizontal space occupied by the individual. The importance of these points is greatly enhanced when the persons concerned are feverish, or weakened by sickness, for what merely causes irksomeness in healthy men will add much to the suffering of these, and may even aggravate their disease. In Evans's waggon, with

seats 1 ft. 2 in. in height, the horizontal space available was only 2 ft. 9 in. at the utmost, and in Locati's, with seats 1 ft. high, the horizontal space was 3 ft., both of them far too small for these heights of seat, while the structure of the vehicles prevented any inclination being given to the back.

There is a strong desire on the part of many persons to have the weight of ambulance waggons largely reduced, without considering fully how far such reduction would affect their durability and usefulness. This question of weight has to be regarded from two points of view—(1) the actual dead weight in the waggon to each person carried, and (2) the manner in which the weight is distributed in the structure itself, and its influence on the draught. As regards dead weight, the Locati waggon, with two recumbent cases, could carry four other persons, including the driver and an attendant, or six in all, with a weight of 329 lb. to each. The Evans waggon, with a similar load, would have a dead weight of 322 lb. to each; and in the heaviest of the English waggons with the same number the dead weight would be 300 lb., but if the number were eight, which the vehicle could carry, it would have been 234 lb. only. In the new pattern ambulance waggon recommended by the committee the weight of the vehicle with all its fittings complete was 18 cwt. 5 lb., and with eight persons, including driver and attendant, the dead weight per man was only 253 lb. With regard to the distribution of the weight, the following facts are of great importance. The waggon of the Ambulance Committee as a whole was 1 qr. 19 lb. heavier than that of Locati, and 3 qr. 5 lb. heavier than Evans's; the body of the vehicle, including axles, springs, and fittings, is lighter than the corresponding parts of Locati's by 1 cwt. 2 qr. 22 lb., and lighter than Evans's by 3 qr. 12 lb. The increase of weight is altogether in the wheels, of which the fore are 36 in. in diameter, the hind 56 in., and both with 2 in. tyres, while they are made of the Madras pattern, with metal naves, which, though heavy, are unequalled as regards strength, suitability for different climates, and facility of repair. The wheels of Evans's, and still more of Locati's waggon, had been reduced, to save weight, until they were no longer serviceable for campaigning, and their draught was most materially enhanced everywhere but on firmly paved streets or roads; and from these an additional hundredweight, or even more, in them would have been a decided advantage for the horses.

It will be borne in mind that the above reflections apply to the ambulance service of troops in the field. In this country, during peace, there can never be the same pressure as after a battle, or with a sickly army, and this will admit of considerable modification of the means employed without material harm accruing. Carriages, too, which are scarcely ever required to move but over paved streets or well-made roads, may prove useful which would tumble to pieces in less than a week in real campaigning, with the rough usage of untrained soldiers; but the principles inculcated, it is believed, are intimately connected with the efficiency of the service everywhere.

THE ETIOLOGY OF TETANUS, AND THE OCCASIONAL VALUE OF NEURECTOMY IN ITS TREATMENT.

By J. A. MACDOUGALL, M.D., F.R.C.S.ED.,
CONSULTING SURGEON TO THE CUMBERLAND INFIRMARY, ETC.

TETANUS has ever been a subject of deep interest to the surgeon, as much for its mysterious causation as for its terrible and all too frequently fatal manifestations. Well-nigh as often the result of a trivial as of a grave injury, and at times appearing unconnected with any traumatism, it is no wonder that since pathology became the science it is to-day, its best efforts should have been devoted to the discovery, if possible, of the morbid conditions which mark a disease, some of the strongest features in which are that the widest and ripest experience may entirely fail to apprehend its advent, to explain why it should have appeared, or to predict with any certainty the anatomical changes which underlie it. And even now the task is unaccomplished, for, great as the progress has been in the demonstration and elucidation of the morbid anatomy of the spinal cord, there yet remains a hiatus in our knowledge as to any one condi-