

Evolution of catgut ligatures: the endeavours and success of Joseph Lister and William Macewen

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And they sewed fig leaves together and made themselves aprons. Genesis 3:7.

It must have been a great convenience to Adam and Eve to have their 'aprons' made of biodegradable material which would reliably disintegrate after a short and regular time interval. It would have been equally, if differently, convenient for the early pre-Listerian surgeons to have a similar material for the subcutaneous ligatures which were needed for amputations, obliteration of major blood vessels to cure aneurysms, or closing the 'ring' in hernia repairs.

Force was required in tying such ligatures which had to be strong. It was recommended, for example, that the inner and middle coats of major arteries should be ruptured to promote thrombosis when pulling the ligature tight. Silk, twine, horsehair and silver wire were some of the materials used. One or both ends of the knot were left long enough to protrude from the wound, partly for drainage, partly for ease of removal. But they also provided a route for infection to enter the depths of the wound and sepsis, pyaemia and secondary haemorrhage were common. What was required was a strong flexible material which could be easily knotted, would remain intact in the tissues until its purpose had been fulfilled and then be completely absorbed or at least made inactive, and be able to be buried totally subcutaneously with no knot ends trailing to the surface. The two surgeons (perhaps the greatest of their era) who solved the problem were Lister and Macewen.

Lister came to Glasgow in 1860 as Regius Professor of Surgery in the University. In 1865, he began the antiseptic era by treating a compound fracture of the lower leg in 11-year-old James Greenlees with carbolic acid and achieving complete healing without infection. Soon afterwards he began his experiments on improving ligature material. He left for Edinburgh in 1869 and subsequently went to London.

Macewen was 21 years younger than Lister and did not graduate in Glasgow until 1870. As a student he must have attended Lister's lectures and ward rounds and he became a firm believer in antiseptics and carbolic acid. Later he was to use asepsis in place of and in addition to some antiseptic techniques. In 1892, he applied for and obtained the post of Regius Professor of Surgery at Glasgow University, and Lister supplied one of his 'testimonials'.

In the *British Medical Journal* of 1881 there appeared in the issue of 29 January a paper by William Macewen entitled 'Clinical lectures on some points connected with the treatment of wounds. Lecture 1. Ligature'. By an extraordinary coincidence the issue of the following week (5 February, 1881) contained the first part of Joseph Lister's Presidential Address to the Clinical Society of London, 'On the catgut ligature'. The second part of his address was published one week later. It is remarkable that the two surgeons who were responsible for the successful development of catgut ligatures should have their observations published within 2 weeks in the same journal. Lister's paper is longer and more detailed than Macewen's and of course they were written for different readerships. To begin with, they covered much the same ground although occasionally Macewen adds a detail which Lister has omitted. In the end they come to similar conclusions, but there is no doubt that

Lister's product was superior to Macewen's. Lister, however, had started his experiments with ligatures while Macewen was still a medical student and, to begin with at least, Macewen had simply followed his master's lead.

With his continuing success with carbolic acid and the antiseptic method of wound healing, it must have seemed to Lister that, if he were to sterilize the material then in use with carbolic acid, a permanently buried ligature might be achieved. It would not be absorbed but might remain inert as some bullets and other foreign bodies occasionally did. He chose silk because its smooth surface made it unlikely to cause physical irritation in the tissues. At first he had some success (see *Lancet* 1869: 451) but he and others had later problems. At best the silk ligature would be encapsulated with fibrous tissue but this was unusual; more often, sooner or later, it was extruded or had to be removed because of pus formation.

There was, however, another strong flexible material, catgut, which had attracted some surgeons but had given disappointing results. When, in the dry state, it was imbedded in the tissues it rapidly absorbed fluid and within 24 h or so it had become soft, pulpy and the knot no longer held. Yet it had many advantages. It was readily available and used, among other things, to string a variety of musical instruments because of its resistance to large breaking strains and its relative lack of stretching when under tension. It was cheap; a gross of hanks (i.e. skeins) cost 12 pence (perhaps £4 or so today) and a single hank cost 1 penny. It seemed to have everything required of a ligature except for the excessive rapidity of its absorption. If this process could be slowed down to an acceptable 2-3 weeks, a useful ligature material would have been found.

Lister visited a catgut manufacturer and was impressed not only by the crudity of catgut preparation but by the beauty of the final product. He is worth quoting:

Catgut, as you are all doubtless aware, is prepared from the small intestine of the sheep. The gut is treated in what seems an exceedingly rude manner for so delicate a structure. It is scraped with some blunt instrument, such as the back of a knife over a board; and by this means, as the people express it, the dirt is scraped out. That which these people call dirt is the exquisite and complicated structure of the intestinal mucous membrane. But, while the mucous membrane is scraped out from within, there is also scraped off from without the circular coat of muscular fibres. The result comes to be that the intestine is converted into a comparatively insubstantial material; this exquisitely delicate structure from which the catgut is prepared is neither more nor less than the sub-mucous cellular coat of the intestine. . . . I was astonished to find that, after this scraping process, the intestine could be blown up still as a continuous tube.

For the thickest form of catgut, the complete tube was attached to a wheel, twisted until tight and then allowed to dry. For the finer kinds, the tube was slit up from inside by a number of razor blades set in a conical piece of wood. Usually the fresh catgut was exposed to the fumes of burning sulphur or bleached by potash. But Lister thought the latter were

unnecessary; it was the twisting and drying that were essential.

Lister used a wide variety of carbolic acid solutions to find out if, thereby, he could retard the absorption process. He could, but the initial preparation took a very long time; 2 months was a minimum, 6 months much better and a year best of all. But this raised problems; a supplier, who had run out of 6 months' stored catgut, was likely to replace it with relatively fresh material causing disastrous clinical results. Lister showed little respect for his suppliers and recommended that the surgeon should make and keep his own ligatures.

He began to suspect that this long period of delay, which was necessary before use, was an inherent property of the catgut and unrelated to his antiseptic solutions. This was confirmed one wet Christmas day when he met an old fiddler going into the Royal Infirmary in Edinburgh to entertain the patients. But the fiddler said that his fiddle would not work properly that day since the wet catgut strings had not been properly seasoned. That catgut could be 'seasoned' in the same sense that wood is seasoned was a new concept to Lister, who realized that some of his early successes with carbolicized gut probably resulted from his use of old well-seasoned gut.

The problem now was to try to shorten this seasoning process and for suitable materials he turned to the leather industry. 'One substance that suggested itself was tannic acid so as to convert the fibrous tissue of the catgut into leather.' He had some success but in one respect tannic acid was a failure. 'I have not obtained by means of tannic acid a kind of catgut that is not too speedily absorbed.' The next substance he used was chromic acid on 'account of its well known effect in hardening tissues'. By itself chromic acid did not work very well but, when mixed with other substances, particularly glycerine, the results proved more hopeful.

Macewen, in 1881, reported that he had been experimenting with catgut prepared in chromic acid and glycerine for some years. A watery solution of chromic acid, one part to five, was added to glycerine in the proportion of one part to two. The hanks of catgut were inserted in this solution and retained there for 7-8 months before being stored in a solution of carbolic acid and glycerine (one to ten) until ready for use. The ligatures were strong and persisted for 2-3 weeks, long enough for clinical purposes. 'Mr. Lister' he writes 'has been endeavouring to

secure a ligature and believes he has now succeeded; but hitherto he has not seen fit to publish his results.'

Lister had 'not seen fit to publish his results' because he wanted to take the method of preparation one stage further and avoid the delay of 7-8 months before use. In his paper of 1881 he announced success and told the Clinical Society of London how it was done. 'I dissolve one part of chromic acid in 4000 parts of distilled water and add to the solution 200 parts of carbolic acid; ... minute as is the quantity of the chromic acid, it exerts, when in conjunction with carbolic acid, a most powerful effect upon the gut.' If the solution was left by itself, some colour changes occurred within a few hours and a reddish grey precipitate formed. If, however, catgut about equal in weight to the carbolic acid was added as soon as the ingredients were mixed, there was little change in colour and no obvious precipitate which was presumed to have been deposited in the catgut. After 48 h the effect of the chromic acid appeared to be complete and the catgut could be removed from the solution, dried and stored in one in five carbolic oil ready for use. Lister tested its rate of absorption firstly by incubation in warm blood serum obtained from the slaughterhouse and secondly from clinical use. He came to the conclusion that 2-3 weeks would pass before 'erosion' and absorption of the ligature would occur.

MacEwen's method worked but the delay of 7-8 months in preparation was a nuisance. Lister had overcome this and produced ligatures that required only a few days preparation while still retaining their delayed rate of absorption. Lister went on trying to improve his catgut ligatures for many years and manufacturers have developed other techniques but the above method, which Lister published in 1881, was really the end of the beginning.

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