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小口径血液导流管的实验研究*

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摘要 目的:探讨小口径血液导流管在动物离断肢体模型中快速恢复通血的实验基础应用,研究小口径血液导流管实验幼猪离断肢体维持通血效果的评价。**方法:**20只实验幼猪随机分为A、B两组,制成后肢完全离断模型模型,采用内径为2.0 mm、外径2.5 mm的血液导流管,A组长度10 cm;B组长度20 cm,进行血管桥接后定期观察血液导流管通畅性,观察终点为血液导流管完全堵塞,血管超声探测仪无血流信号,远端血管搏动消失,离断肢体以远皮下毛细血管网无渗血。比较两组到达观察终点的时间有无差异。**结果:**建立临时血管通路后,离断肢体远端股动脉的远端有搏动,血管超声探测仪可检测到血液导流管内有血流信号,随着时间的延长,血液导流管动脉段逐渐由鲜红色变为暗红色,导流管段逐渐形成附壁血栓,远端血管搏动及皮下毛细血管网渗血逐渐减弱直至消失,血流信号消失,两组到达观测终点的时间分别为A组 365 ± 47.4 min;B组 359 ± 31.5 min,两者比较其差异没有统计学意义($P > 0.05$)。说明长度在10 cm-20 cm的小口径血液导流管在实验动物离断肢体血管通血方面无明显差异。**结论:**小口径血液导流管能够用于动物离断肢体的血管临时桥接,维持通血时间可达6-8小时,有效通血时间长。实验数据说明小口径血液导流管适合于动物离断肢体模型中的血管桥接,在下一步临床应用中在四肢复杂血管损伤中有着较为广阔的应用前景。

关键词: 小口径血液导流管;肢体血管离断模型;猪;血管桥接

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The Experiment Study of Small Diameter Intravascular Catheter*

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ABSTRACT Objective: To explore the the experimental application of small diameter intravascular catheter using on animal amputated limb model in order to quickly recover blood supply and to discuss the evaluation of small diameter intravascular catheter using in experimental piglets. **Methods:** There are 20 experimental piglets which are divided into groups A and B randomly. They are established to amputated limb model using the small diameter intravascular catheter of inner diameter of 2.0 mm and outside diameter 2.5 mm. Length in group A is 10 cm and group B 20 cm. To observe the patency after Vascular bridge connection. The observation endpoint with the intravascular catheter completely blocked were as follow: no blood flow signal on Doppler ultrasound and no pulse in distal blood vessel and distal amputated limb without bleeding. Comparing the differences of time endpoint of two groups differences. **Results:** After established temporary vascular access, the distal femoral artery of amputated limb start to pulse and vascular Doppler ultrasound can detect the signal of blood flow. With the extension of time, the color of diameter intravascular catheter changed from red to dark red with the thrombus formation in inner catheter. The pulse of distal vascular are gradually weakened. The exudation of subcutaneous blood capillary net are also disappeared. The time endpoint of two groups are respectively group A (365 ± 47.4 min) and group B (359 ± 31.5 min). Compared with the differences between two group, it has no statistical significance ($P > 0.05$). To show that small diameter intravascular catheter (length from 10 cm to 20 cm) in experimental animals have not obvious differences with Vascular bridge connection. **Conclusion:** Small diameter intravascular catheter can be used in animal amputated limb model in order to bridge vascular temporarily. It can maintain blood shunt from six to eight hours. And effective time is longer than others. Experimental data shows that small diameter intravascular catheter is suitable for animal amputated limb model in vascular bridge connection. In the next step, it can be widely used into the complicated injury of amputated limb in clinical application.

Key words: Small diameter intravascular catheter; Amputated limb model; Pig; Vascular bridge connection

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前言

通过对近些年来,诸多机器伤、车祸伤等病人来院就诊的情况进行分析和总结,明确紧急快速恢复肢体血供是肢体重建

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中最重要的问题。对于肢体离断伤的救治过程中,由于大多数均合并有血管损伤,对于没有救治条件的基层医院,由于没有显微相关器械及技术^[1],这类病人的转院途中发生离断肢体持续缺血,软组织及肌肉发生无氧酵解,乳酸堆积,甚至于缺血性肌挛缩、肌肉坏死、急性肾功能衰竭等诸多并发症^[2],往往导致后期救治中对于可能挽回的肢体,因救治进一步延迟的后果,最终导致截肢。

虽然近年来小口径人工血管的研究很多^[3-6],但其管壁顺应性差;稳定性差;需要显微外科技术吻合血管技术;人工血管造价较高^[7];搬运伤病员途中容易发生血管撕裂等缺点,说明其并不适合于离断肢体的临时血管导流。通常这类患者转院途中需要花费很多的时间,如果没有临时血管桥接离断肢体,就不可避免的造成了离断肢体的持续缺血,失去了重建肢体血供的黄金时间,最终导致截肢的结果。我们通过对聚乙烯管的表面改性(肝素化抗凝处理),得到一种小口径血液导流管,用于离断肢体的临时快速通血。小口径血液导流管的优势:(1)血液导流管相对人工血管等高分子材料造价低,导管弹性好;(2)管壁硬度相对硅胶、医用塑料等生物材料较强,临时固定时不容易发生管壁塌陷等情况,适合紧急救治中使用;(3)同时对导管内壁肝素化后能够在 6-8 小时内持续释放肝素抗凝,短时间内能够维持导管的通畅;(4)导管连接方便快捷,只需连接血管后用 1# 丝线捆扎固定,在最短的时间恢复离断肢体的通血,减少因缺血缺氧导致发生离断肢体软组织、肌肉等发生坏死的几率。基于此优势,我们开展此项实验研究,旨在探讨:(1)小口径血液导流管在动物实验中的可行性;(2)实验动物膝关节以远离断肢体通血效果评价;(3)不同长度小口径血液导流管在维持肢体通血时间方面有无明显差异。现报道如下:

1 材料与方法

1.1 实验动物及分组

20 只实验幼猪做为实验对象(第四军医大学第一附属西京医院动物实验中心提供),体重 20 ± 3 kg,数字化随机分成 A、B 两组,每组 10 只。A 组采用血液导流管 10 cm;B 组采用血液导流管 20 cm。

1.2 麻醉方法

采用速眠新(陆眠宁)注射液,剂量为 0.1 mL/kg,等麻醉起效后再肌注 2% 戊巴比妥溶液(1 mL/kg,先注射总量的 1/3,随后根据实验幼猪麻醉情况追加),将猪麻醉后,仰卧位四肢固定于手术台。

1.3 断肢模型建立

实验幼猪双后肢剃毛备皮,仰卧位四肢固定于实验动物手术台上,张口牙垫固定。双后肢常规碘伏消毒后铺巾,消毒范围手术切口周围 10 cm。常规碘伏消毒后铺单,Marker pen 标记体表位置,于双后肢体表可触及肌间沟,切皮长度 8-10 cm,逐层切开皮肤及皮下筋膜层,可见一浅表静脉穿肌肉间隙进入深部,沿此间隙仔细分离软组织及肌肉,采用乳突撑开器或甲状腺拉钩暴露手术视野,沿着肌间隙仔细上下游离 10 cm 左右深层可见股动脉及静脉,钝性游离血管及周围组织,剥离血管外膜,游离股动静脉上下两端全长 10 cm,近心端及远心端各套线作牵引、标记用,从后肢膝关节平面切关节囊及周围韧带

组织,完全游离膝关节以下平面,用外固定架固定离断肢体。血管夹阻断近心端及远心端,切开放动脉及静脉,滴注少量罂粟碱溶液(1 mg/mL)防止血管痉挛。模型建立完毕。

1.4 血液导流管连接方法

头戴式 3-5 倍显微镜下使用显微器械修剪血管口及外膜,肝素钠盐水冲洗管腔,左侧肢体选择 10 cm 的血液导流管,右侧肢体选择 20 cm。于近心端插入,用 1-0 慕丝将导管与血管近端捆扎固定,先开放近心端血管夹,待气体经血液导流管排净后再夹闭近心端,插入血液导流管后捆扎远心端,松开双侧血管夹,观察血管通血情况及肢体血供恢复情况。

1.5 数据采集及结果的观察

1.5.1 数据采集时间 导管连通后,每 30 min 观察一次,观察 2 小时后每 1 小时观察一次,最终血管超声探测仪提示无血流信号后停止观察。

1.5.2 观察指标及方法 观察血管颜色、血管搏动情况、离断肢体远端皮下毛细血管渗血情况;心电监护仪+腕带式血氧饱和度测定器监测离断肢体远端血氧饱和度及温度的变化;便携式血管超声探查仪检测血液流动信号;实验幼猪采静脉血测定凝血指标对比观察。

1.6 统计学数据

采用 SPSS19.0 统计软件进行分析。计量资料以均数 $\pm$ 标准差表示,两两比较采用配对 t 检验;组间比较采用独立样本 t 检验;检验水准 $\alpha=0.05$ 。

2 结果

实验幼猪股动脉的口径为 2.0-3.0 mm,A 和 B 两组导流管在快速连接后均可见血液快速通过导管内从近端到远端,离断肢体以远股动脉搏动有力,皮温逐渐开始上升,皮色由苍白转为红润,皮下筋膜层渗血明显,针刺远端末梢出血活跃,血管超声探测到血液流动。随着时间延长,导流管血液颜色开始变为暗红色,离断肢体远端皮下渗血消失,便携式血管超声提示无血流信号。

2.1 血管通畅时间

血液导流管能够可用于口径 2.0~3.0 mm 的动静脉的临时桥接,到达观察终点的时间:A 组 365 ± 47.4 min;B 组 359 ± 31.5 min,两者比较其差异没有统计学意义($P=0.727>0.05$),A、B 两组维持通血时间无明显差异。

2.2 离断肢体及全身血氧饱和度测定

实验用猪后肢离断模型血氧饱和度监测在通血后 30 min 后开始逐渐上升,通血 2-8 h A 组血氧饱和度维持在 $86 \pm 5.0\%$ 之间,B 组维持在 $83 \pm 4.8\%$ 。两者比较其差异没有统计学意义($P=0.117>0.05$),A、B 两组离断肢体血氧饱和度监测无明显差异。

2.3 体温变化曲线

实验用猪后肢离断模型体温监测在通血后 30 min 后开始逐渐上升(室温 25°C),通血 4 h A 组体温变化范围 33.1°C - 36.6°C 之间,B 组 32.2°C - 35.4°C 。提示两组体温变化趋势无明显差异。

2.4 凝血功能检测

20 例实验幼猪在术前、术后均静脉抽血 2 mL,采用法国

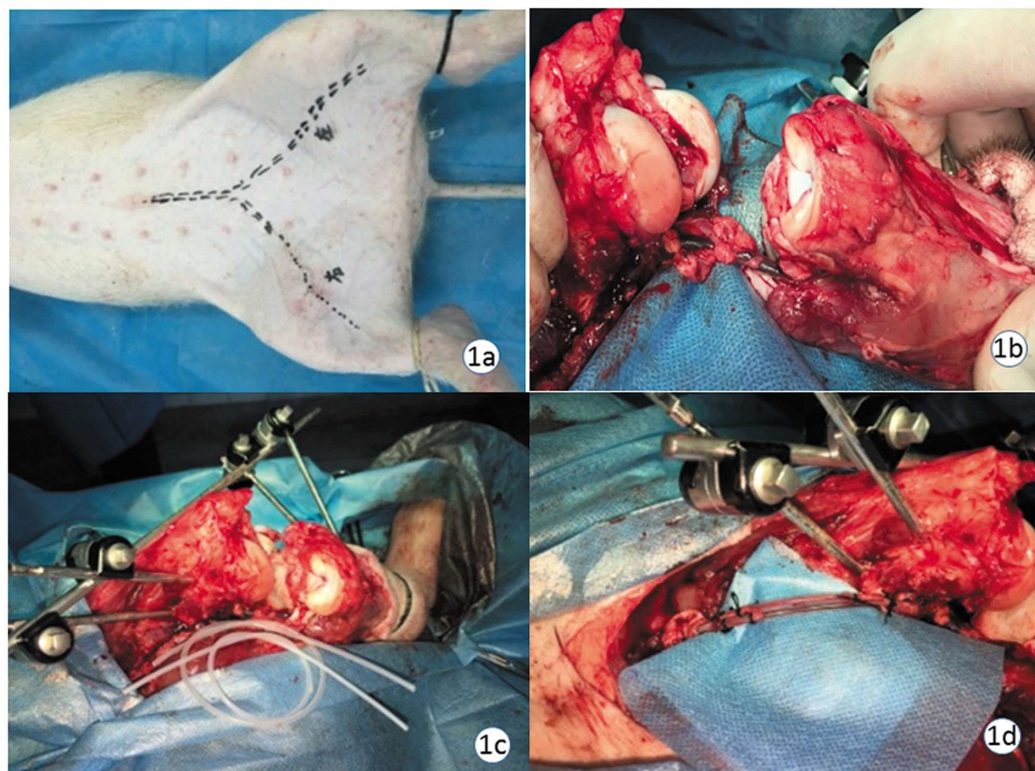


图 1a 手术切口示意图 图 1b 断肢模型建立 图 1c 小口径血液导流管

图 1d 血液导流管接通后血管远端搏动良好,血管超声探测血流信号稳定

Fig.1a Surgical incision Fig.1b Amputated limb model Fig.1c Small diameter intravascular catheter Fig.1d After connection good impulse and vascular ultrasound detecting blood flow signal

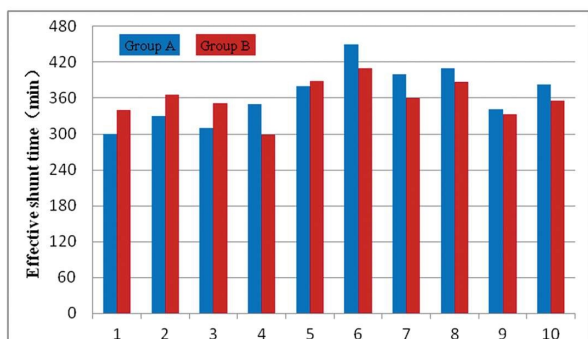


图 2 A、B 两组有效血液导流时间

Fig.2 Effective shunt time of Group A and B

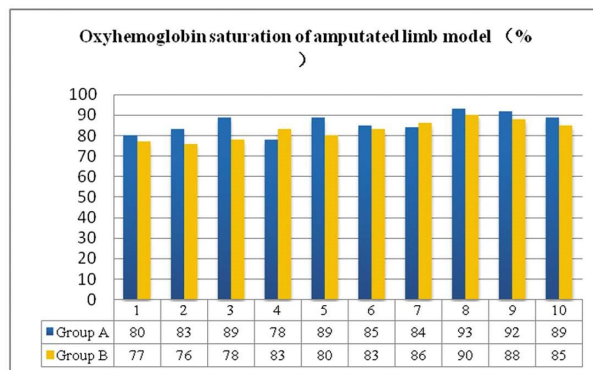


图 3 A、B 两组血氧饱和度对比

Fig.3 Contrast of oxyhemoglobin saturation in Group A and B

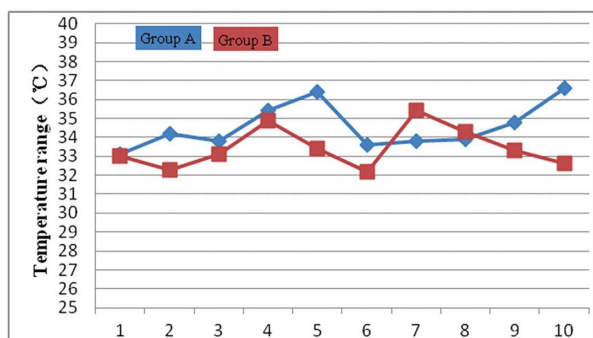


图 4 A、B 两组离断肢体温变化对比

Fig.4 Temperature range in Group A and B

STA Compact 全自动凝血仪^[8]检测凝血功能各项指标:凝血酶原时间 (PT)、部分活化凝血酶原时间 (APTT)、纤维蛋白原

(FiB)、D-二聚体(D-D)四项指标检测,对比结果显示:两组使用小口径血液导流管对实验猪凝血功能均无影响,术前术后对比无明显差异($P>0.05$)。

3 讨论

本实验使用小口径血液导流管(肝素化聚乙烯管)在动物离断肢体模型中桥接主要动静脉,快速恢复离断肢体血运,通血后在 6-8 小时内能够保证导管的通畅,进一步提示血液导流管在实验动物离断肢体桥接血管快速通血的适用性,同时血液导流管连接简单、快捷,只需要插入血管断端后用丝线环形捆扎。通过动物实验数据提示临时血液导流管(规格 2.0 x 2.5 mm)选择 A 组 10 cm, B 组 20 cm 接通后其通血时间,离断肢

表 1 实验幼猪术前术后凝血功能对比

Table 1 Contrast of piglet blood coagulation between pre-operation and postoperation (n=20)

	PT(s)	APTT(s)	FiB(g/L)	D-D(mg/L)
Pre-operation	14.5± 0.4	42.1± 2.9	2.0± 0.3	0.3± 0.2
Postoperation	14.4± 0.7	43.3± 3.5	2.1± 0.4	0.3± 0.1
F value	0.98	1.97	0.33	1.56
p	>0.05	>0.05	>0.05	>0.05

体血氧饱和度及体温无明显差异,且通血时间能达到 6-8 小时,提示 10-20 cm 小口径血液导流管在实验动物离断肢体临时桥接供血中有着比较大的优势,且其物理特性好,有着较好弹性,抗压和抗拉伸能力较好,20 例动物均没有出现导管脱出,导管成角卡压闭塞管腔等现象,使用导管术前术后 20 只实验幼猪凝血功能对比无明显差异,本实验为离断肢体的快速通血救治提供可靠的实验依据。

小口径血液导流管的特点:(1) 将小口径血液导流管应用在四肢肘、膝关节以远离断肢体的中能够实现快速通血,恢复肢体血供,减少因缺血缺氧导致发生肢体坏死等并发症;(2)能够在一线紧急救治同时开展,连接导管快捷、方便,最快的速度实现离断肢体恢复血供;(3) 术前准备及术中能够在离断肢体通血的条件下完成清创、骨折固定、神经肌腱探查修复以及皮瓣的切取,节省了大量的时间,为后期保肢成功提供了最为可靠的基础条件;(4)连接导管后离断肢体血液流体力学分析:由于血液导流管只需要在短时间内(6-8 小时内)保持通畅,通血后血管 B 超检查提示导管内壁随着附壁肝素的逐渐流失,导管内逐渐形成附壁血栓,使得导管内血液流速逐渐变慢,导管内血液的容量也是逐渐减小,但在 6-8 小时黄金时间内离断肢体血氧饱和度、体表温度无明显差异,术前及术后两组实验幼猪的全身血凝指标无明显差异。说明小口径血液导流管能够在肢体离断治疗的黄金时间 6-8 小时内维持导管的通畅,同时减少离断肢体的缺血再灌注损伤,避免发生无氧酵解及离断肢体远端软组织、肌肉组织及骨组织发生坏死等并发症,能够有效的恢复实验幼猪离断肢体的血供,在短时间内导流管能够起到临时快速有效通血的要求,达到实验目标。

对于四肢复杂血管损伤,特别是肘关节、膝关节以远的肢体离断,临床一线医生在处理的过程中存在诸多问题^[89],例如转院时间过长,肢体保存方式方法错误,离断肢体长时间缺损等等。大多数离断肢体在术前评估的时候由于缺血时间过长,部分肌肉组织,软组织甚至于骨组织发生坏死,增加了术前预判保肢截肢的难度^[90]。即使花费较长的时间来保肢,最后肢体发生缺损再灌注损伤,肌肉坏死、急性肾功能衰竭等并发症,为了患者的生命,让我们不得不采取截肢的手术方法。参照人体解剖学血管口径数据^[11-14],对于成人肘、膝关节以远的肢体离断,桡动脉、尺动脉、胫前动脉、胫后动脉以及伴行静脉的口径均为 2-3 mm,与小口径血液导流管管径相符,在现场紧急救治过程中如果能采用小口径血液导流管(规格 2.0 × 2.5 mm)进行离断肢体的快速通血,就能在后送途中避免出现肢体持续缺血,软组织及肌肉发生坏死等并发症,将会给该类患者的保肢

成功提供先决条件,同时通过实验数据我们可以得出 10-20 cm 范围的血液导流管在维持离断肢体血供无明显差异。

临床应用展望:将血液导流管应用于临床工作中去,存在诸多问题,例如导管的血液相容性,抗凝性及操作的注意事项等等,需要在进一步完善导管的改进与研究。如果能在现场救治过程中使用血液导流管快速恢复离断肢体的血供,为后期的保肢手术创造基础条件,避免发生离断肢体缺损坏死,一线紧急救治环节能够将离断肢体在通血的前提下送往有条件的救治医院,将会给该类患者的保肢成功提供更为切实有效的保证,有效提高保肢率。临床上为小口径血液导流管在四肢复杂血管损伤中临时快速通血的应用奠定了实验基础,提供了可行性理论依据。

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