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· 临床研究 ·

混合现实技术辅助股前外侧皮瓣穿支血管定位解剖的临床应用

袁宗毅, 明华伟, 张兴安, 韩新生, 王华东, 李婷, 陈方园, 谭小尧

南充市中心医院口腔颌面外科, 四川 南充(637000)

【摘要】目的 探讨混合现实技术定位穿支血管及辅助穿支血管解剖在制取股前外侧皮瓣的临床应用价值。**方法** 收集南充市中心医院口腔颌面外科2020年1月至2021年1月6例口腔颌面部肿瘤切除后需行股前外侧皮瓣修复患者,术前将携带校准点的患者双下肢CT血管成像数据导入数据工作站,对双下肢穿支血管及其周围组织进行三维重建,并将重建结果导入 Microsoft HoloLens 2眼镜。术中通过术区校准点进行校准,使术前重建结果借助 Microsoft HoloLens 2眼镜重合投射在术区,从术前是否重建出穿支血管、穿支血管实际走行是否符合重建结果、穿支点实际位置与术前重建结果偏差是否在1 cm内、是否发生穿支血管损伤等方面分析混合现实技术辅助股前外侧穿支皮瓣穿支血管定位解剖的临床应用价值,并记录取瓣所需时间、术中所需校准时间。**结果** 6例患者均在术前顺利重建出穿支血管位置及走行,术中穿支血管实际走行均符合重建结果,穿支点实际位置与术前重建结果偏差均在1 cm内,符合股前外侧皮瓣实际制备要求,所有病例均无穿支血管损伤发生;平均制取皮瓣时间为 (70.50 ± 7.20) min;平均校准时间为 (13.33 ± 5.50) min;术后皮瓣均存活。**结论** 混合现实技术将股前外侧穿支血管重建结果直接投射在术区,为辅助定位及解剖股前外侧皮瓣穿支血管提供一种新方法,减少了损伤穿支血管的可能性。

【关键词】 股前外侧皮瓣; 穿支血管; 穿支皮瓣; 手术导航; 虚拟手术; 混合现实技术; 校准点; 口腔恶性肿瘤; 口腔颌面部组织缺损; 修复重建

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Clinical application of the mixed reality technique to assist the location and anatomy of perforator vessels of the anterolateral femoral flap YUAN Zongyi, MING Huawei, ZHANG Xing'an, HAN Xinsheng, WANG Huadong, LI Ting, CHEN Fangyuan, TAN Xiaoyao. Department of Oral and maxillofacial surgery, Nanchong Central Hospital, Nanchong 63700, China

Corresponding author: TAN Xiaoyao, Email: 360195707@qq.com, Tel: 86-817-2290950

【Abstract】Objective To explore the clinical application value of mixed reality technology in locating perforator vessels and assisting perforator vessel dissection to harvest anterolateral thigh flaps. **Methods** Six patients who needed anterolateral thigh flap repair after resection of oral and maxillofacial tumors were recruited from the Department of Oral and Maxillofacial Surgery of Nanchong Central Hospital from January 2020 to January 2021. Before surgery, the CT angiography data of the lower limbs of the patients carrying the calibration points were imported into the data workstation to perform 3D reconstruction of the perforator vessels and surrounding tissues of the thigh, and the reconstruction results were imported into Microsoft HoloLens 2 glasses. During the operation, calibration was performed at the calibration point of the operative area so that the preoperative reconstruction results were superimposed on the operative area through Microsoft HoloLens 2 glasses. The clinical application value of mixed reality technology assisted perforator

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【作者简介】 袁宗毅,主治医师,博士,Email:282338647@qq.com

【通信作者】 谭小尧,主任医师,本科,Email:360195707@qq.com, Tel:86-817-2290950



微信公众号

vessel location and anatomy of anterolateral femoral perforator flap was discussed from six aspects: whether the perforator vessel was reconstructed preoperatively, intraoperative calibration time, whether the actual position of the perforating vessels passing through the fascia lata fulcrum deviated from the preoperative reconstruction result within 1 cm, time required to harvest the flap, and whether the actual route of the perforator vessel was consistent with the reconstruction result, and whether the postoperative flap survived. **Results** The position and course of perforating vessels were successfully reconstructed in 6 cases before the operation. The actual course of perforating vessels during the operation was consistent with the reconstruction results. The deviation between the actual position of the perforating points and the preoperative reconstruction results was within 1 cm, which met the requirements of the actual assisting of the anterolateral thigh flap. The average time of flap harvest was (70.50 ± 7.20) min. The average calibration time was (13.33 ± 5.50) min. All flaps survived. **Conclusions** Mixed reality technology projects the reconstruction results of anterolateral femoral perforator vessels directly into the operative area, which provides a new method for assisting localization and anatomy of anterolateral femoral flap perforator vessels and reduces the possibility of injury to perforator vessels.

【Key words】 anterolateral thigh flap; perforating vessels; perforators flap; surgery navigation; virtual surgery; mixed reality technique; calibration point; oral malignancy; oral and maxillofacial tissue defects; reconstruction

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股前外侧皮瓣可制备为股前外侧肌皮瓣、阔筋膜下或阔筋膜上的穿支皮瓣^[1-2],其中阔筋膜上股前外侧穿支皮瓣具有轮廓外形良好、厚度合适、供区并发症更少等优点,已被广泛应用于口腔颌面部组织缺损修复重建中^[3]。在制取该类型皮瓣的过程中准确寻找到穿支点、保护穿支血管是手术成功的关键。混合现实技术是继虚拟现实技术、增强现实技术之后的全新一代数字全息影像技术。它将虚拟世界与物理世界结合在一起^[4]。已有学者将混合现实技术应用在腹壁下动脉穿支皮瓣的制备中,用以定位穿支血管在皮下组织的位置^[5]。混合现实技术可以将术前重建影像直接投影在术区,使术者在术前预知术区穿支血管的位置、走行及其与周围组织的关系,并以此为依据设计切取股前外侧皮瓣。本研究拟通过利用混合现实技术辅助股前外侧皮瓣制取的特点及其存在的问题,探讨其临床应用价值。

1 资料和方法

1.1 一般资料

选取南充市中心医院2020年1月至2021年1月口腔颌面部恶性肿瘤切除后需行股前外侧皮瓣皮瓣修复患者,术前与患者就混合现实技术在股前外侧皮瓣术中导航的优势和不足进行沟通,本研究已通过南充市中心医院伦理批准,并获得患者知情同意。纳入标准:①口腔颌面部恶性肿

瘤切除后组织缺损,需行股前外侧皮瓣修复的患者;②理解并同意使用该技术且愿意接受该技术所需相应检查的患者。排除标准:①拒绝术者使用混合现实技术进行手术导航的患者;②拒绝接受该技术所需相关检查患者;③恶性肿瘤局部晚期或远处转移无手术指征的患者;④高血压病、糖尿病无法得到稳定控制的患者;⑤股前外侧术区既往外伤史或手术史患者。最终纳入病例6例,其中,男性4例,女性2例;颊癌扩大切除软组织缺损患者4例,舌癌扩大切除软组织缺损患者2例,见表1。

1.2 数据收集及建模

患者术前在左侧股前外侧术区暂时固定高分子材料校准点,于校准点处标记校准点位置,行双下肢CT血管造影(CT angiography, CTA)检查,扫描层厚为0.6 mm。检查完毕后保留校准点标记,去除校准点,纱布覆盖保护校准点位置标记。CTA数据以DICOM格式导入三维医学影像工作站进行数据处理,并对所得三维模型进行平滑、包裹、打磨、镂空、轮廓线编辑等优化,组合模型,完成术区三维重建。

1.3 Hololens眼镜的术中使用流程

将上述三维重建模型数据导入Microsoft HoloLens 2(微软,美国)眼镜中。术前评估穿支血管情况,初步确定皮瓣切取范围。术中全麻后调整好患者体位,依照标记重新固定校准点,并进行图像

表1 6例行股前外侧皮瓣修复口腔颌面部组织缺损的患者资料

Table 1 Clinical data of 6 cases of oral tissue defects reconstructed by anterolateral thigh flap

Case	Gender	Age/year	Types of disease	Regions of tissue defects	Content of reconstruction
1	Male	69	Squamous cell carcinoma of the left buccal-gingiva cancer (T4N0M0)	Left cheek, partial mandible and mouthfloor	Left cheek and mouthfloor
2	Female	62	Mucoepidermoidcarcinomaof left cheek (T2N1M0)	Left cheek	Left cheek
3	Male	53	Squamous cell carcinoma of the rear of right tongue (T2N0M0)	Right tongue and mouthfloor	Right tongue and mouthfloor
4	Male	61	Squamous cell carcinoma of ventrum of left tongue (T2N1M0)	Left tongue and mouthfloor	Left tongue and mouthfloor
5	Female	71	Squamous cell carcinoma of the right buccal cancer (T2N0M0)	Right cheek	Right cheek
6	Male	49	Squamous cell carcinoma of the left buccal cancer (T2N1M0)	Left cheek	Left cheek

校准。校准完毕后图像重叠于术区,术者佩戴眼镜,依照 Microsoft Hololens 2 眼镜中穿支血管的位置设计皮瓣,将穿支点设计在皮瓣中央位置。同时在股前外侧术区仍标记髂嵴线及其中点,为寻找穿支血管提供备用参考。术中穿支点的实际位置与混合现实叠加模型所在穿支点位置差距在 1 cm 内则记录为重建模型穿支点位置与实际穿支点位置相符,因为 1 cm 的误差并不足以影响皮瓣的临床设计及制取^[6]。手术开始取下眼镜,切开皮肤、皮下组织、阔筋膜,翻起皮瓣至重建穿支点周围约 1 cm 区域,探查验证穿支点存在。解剖出穿支点后再次佩戴眼镜,参考混合现实重建模型中穿支血管与周围肌肉的关系及其走行自穿支点逆向解剖穿支,完成阔筋膜上股前外侧穿支皮瓣制取。

1.4 评价分析

从术前是否重建出穿支血管、穿支血管实际走行是否符合重建结果、穿支点实际位置与术前重建结果偏差是否在 1 cm 内、是否发生穿支血管

损伤分析混合现实技术辅助股前外侧穿支皮瓣穿支血管定位解剖的临床应用价值,并记录取瓣所需时间、术中所需校准时间。

2 结果

2.1 混合现实技术应用情况

6 例患者均在术前通过 CTA 重建出术区股前外侧穿支血管并导入 Hololens 2 眼镜中,其中有 5 例为肌皮穿支,1 例为肌间沟穿支。术中逆行解剖穿支血管发现血管在肌肉、肌间沟的走行与三维重建结果均相符;翻起阔筋膜后于阔筋膜深面由内向外向着参照 Hololens 2 眼镜投射重建出的穿支点位置解剖,均在重建穿支点周围 1 cm 内解剖出穿支血管;穿支血管均无意外损伤;6 例混合现实技术辅助股前外侧皮瓣制取时间为 (70.50 ± 7.20) min;术中经过校准点校准后投射在术区并标记,平均所需校准时间为 (13.33 ± 5.50) min;术后皮瓣均存活。见表 2。

表2 6例混合现实技术辅助股前外侧皮瓣穿支血管定位手术情况

Table 2 Operation results of 6 cases of the location of perforator vessels in anterolateral thigh flap assisted by the mixed reality technique

Case	Preoperative reconstruction of perforator vessels	Reconstructed model is consistent with the actual anatomy of perforator vessels	Deviation between the actual position of the pivots and the reconstructed position is within 1 cm	Injury of perforator vessels during operation	Time of harvest anterolateral femoral flap*/min	Intraoperative calibration time#/min
1	Yes	Yes	Yes	No	62	24
2	Yes	Yes	Yes	No	71	9
3	Yes	Yes	Yes	No	74	12
4	Yes	Yes	Yes	No	63	14
5	Yes	Yes	Yes	No	81	11
6	Yes	Yes	Yes	No	72	10

*: average = (70.50 ± 7.12) min; #: average = (13.33 ± 5.50) min

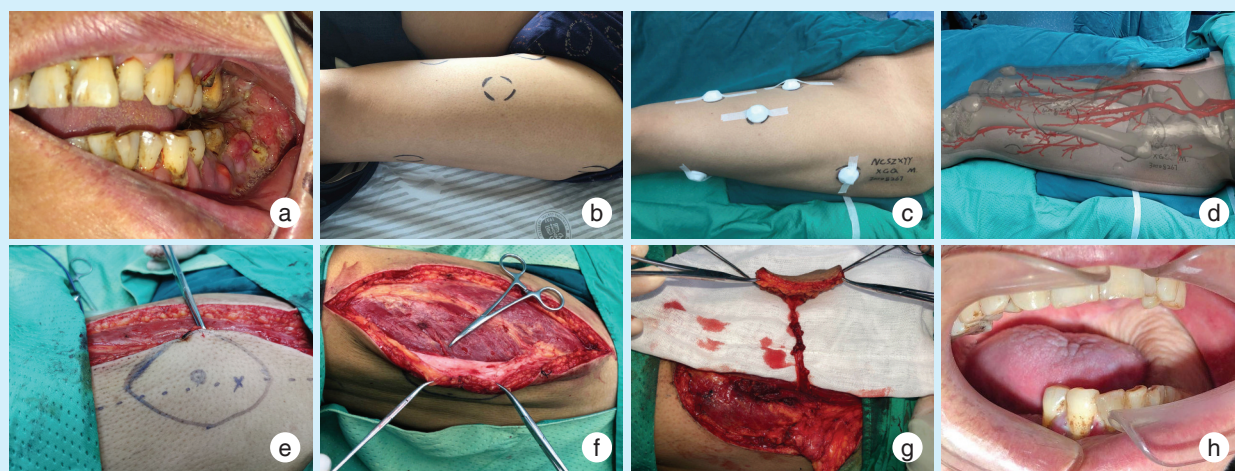
2.2 混合现实技术辅助股前外侧皮瓣穿支血管定位典型病例

患者,男性,69岁,因发现左颊新生物1年余入

院。入院后行左颊病变切取活检术,病检结果回示(左颊-下牙龈)鳞状细胞癌。入院诊断:左颊-下牙龈鳞状细胞癌(T4N0M0)。术前进行双下肢

CTA 检查,确定患者体位后于左侧股前外侧术区暂时固定校准点,并标记校准点位置,然后推入造影剂,嘱患者保持静止,开始扫描,扫描完成后取下校准点,纱布覆盖保护标记。以 DICOM 格式将扫描数据导入三维医学影像工作站(安徽紫薇帝星科技)进行数据处理,重建股前外侧术区血管及周围组织。所得三维重建数据导入 Microsoft Hololens 2 眼镜中。完善术前检查及术前准备后行全麻下左颊-下颌牙龈鳞癌扩大切除术+左下颌骨节段性切除术+左侧颈淋巴清扫术+左股前外侧皮瓣修复术+血管吻合术。全麻后摆好体位,依照标记将校准点重新固定。股前外侧皮瓣切取

手术开始前术者佩戴眼镜进行一次校准,确定穿支血管位置,并标记于体表,以此为中心设计皮瓣。取下眼镜,根据上述标记穿支点位置,寻找穿支血管,穿支点实际位置距重建出的穿支点位置不足 1 cm。穿支点位置明确后再次佩戴眼镜,沿股直肌与股外侧肌肌间沟内参考混合现实影像寻找到旋股外动脉降支,最终解剖出完整的穿支血管,并保留阔筋膜。得到阔筋膜上股前外侧穿支皮瓣,穿支点位于皮瓣中央,穿支血管无损伤。术后皮瓣未出现血管危象,伤口一期愈合。患者术后 4 个月复查,皮瓣存活良好,未见复发或转移。见图 1。



a: primary tumor; b: the calibration point mark for performed CT angiography before operation to determine the left anterolateral femoral operation area; c: after general anesthesia, the calibration point was placed again according to the original position; d: after calibration, the reconstructed images were overlapped and projected on the operation area; e: the midpoint of the anterior superior iliac spine and the lateral margin of the patella (×), position of perforator vessels projected by mixed reality image (⊗); f: actual position of perforator vessels; g: anterolateral thigh flap was prepared; h: condition of flap and primary focal area in four months after operation

Figure 1 Typical case of oral and maxillofacial tissue defect reconstructed with anterolateral femoral flap assisted by mixed reality technique

图 1 混合现实技术辅助股前外侧皮瓣制取修复口腔颌面组织缺损的典型病例

3 讨论

股前外侧皮瓣的血运来源于旋股外动脉降支及其伴行静脉的穿支血管,穿支血管组(动脉和伴行静脉)直径仅为 0.3~2 mm^[7]。一侧股前外侧区通常存在 3 个左右的穿支^[8]。制取股前外侧皮瓣成功的关键是穿支血管的定位及解剖。最经典的定位方法为参考髂嵴线中点寻找穿支点^[9],该方法应用多年,具有一定参考价值,至今仍被广泛应用。随着影像学技术的不断发展,应用高频彩色多普勒超声和双下肢 CTA 可实现个体化穿支定

位,为手术提供更精确的参考,但其为二维图像,且成像范围有限,无法立体呈现出术区的解剖结构^[10-11]。CTA 通过断层扫描血管成像的方式将术区穿支血管及其周围组织解剖结构关系客观真实地呈现出来,但需术者在断层平面影像和术区之间反复交换视线,无法直观地将影像学资料与术区结合起来。本研究中 6 例股前外侧皮瓣术前应用混合现实技术将股前外侧术区穿支血管及周围组织结构的 CTA 扫描数据进行三维重建,得到穿支点位置及血管走行,并将重建结果导入 Hololens

2眼镜,使CTA影像学资料经重建后直观地重叠投射在术区,方便术者实时结合术前CTA影像学资料实施手术。

混合现实技术将虚拟影像与术区重叠的关键在于术区的校准点,Micosoft Hololens 2眼镜通过追踪系统追踪术者视觉,确定合成的影像在系统坐标系中的位置,并且通过光学合路器将虚拟手术影像叠加在术者的视野中。在理想的状态下,虚拟模型与术区可以做到完全融合,达到真正的手术导航效果^[12-13]。但在实际应用中,校准点的匹配并不是完全准确的,甚至会由于校准点的存在带入误差。一项对于混合现实技术定位小腿外侧穿支血管的研究结果显示,经过校准后,混合现实重建穿支血管的位置与实际穿支血管位置存在1.35~3.18 mm误差^[14]。本研究中由于股前外侧区可供校准区域的软组织丰富,活动度及可让性更大,随着体位的变动,校准点之间的相对位置产生变化更大,术中探查重建出的穿支点位置在实际穿支点位置结果仅能控制误差在0.5~1 cm内。尽管如此,由于股前外侧皮瓣修复口腔颌面部组织缺损时,切取皮瓣范围通常大于2 cm×2 cm,因此目前基于校准点配准的混合现实技术仍具备实际应用价值。此外,选取如髌骨、髌前上棘等表面软组织相对稳定的位置作为校准点,增加校准点数量,增加校准点之间的相对距离可以减小上述误差。

另外,对于软组织手术而言,混合现实术前重建模型为固态模型,不能随着术区的组织位移进行同步调整,因此实现混合现实技术导航非刚性术区(如腹部组织器官)手术存在一定困难^[15]。本研究发现,当股前外侧术区切开后,术区产生形变,固态的重建模型已不能反映术区情况,校准点失去作用,无法完全依照虚拟模型导航出的路径进行穿支血管的进一步解剖,因此仅将重建模型作为手术参考用以辨别股外侧肌内穿支血管走行。Marcus等^[16]的研究结果显示,混合现实模型叠加在术区对术野有遮挡作用,会影响手术操作及降低手术安全性。本研究中,将重建模型透明度调低后,混合现实重建出的股前外侧模型对于术区仍具有一定的遮挡作用,影响解剖穿支血管这类精细操作。因此6例股前外侧皮瓣在定位到穿支点位置并解剖到实际穿支点后,手术操作不再完全依赖虚拟模型,而是改为参考其显示的穿支血管走行方向,对穿支血管进行进一步解剖,这

对于在肌肉内走行复杂的肌皮穿支解剖具有较大帮助。当逆行解剖肌肉内的穿支血管遇到穿支血管分叉时,重建模型能够帮助术者判断穿支血管分叉是来源于皮瓣血管蒂还是分支进入肌肉的血管,因此,本研究中所有病例均顺利解剖出完整血管蒂,未损伤穿支血管,且术后皮瓣均顺利存活。与传统方法不同的是,混合现实技术在手术开始前需要先进行校准使模型重叠于术区进行穿支点标记,且此步骤需在手术室内,患者全身麻醉下,体位固定后进行,本研究中,6例病例平均所需校准时间为(13.33±5.50) min,且该时间段无法与麻醉及其他手术准备时间重合,增加了患者整体麻醉时间。尽管如此,由于该技术简化了探查穿支点以及解剖肌皮穿支血管这两项操作,股前外侧皮瓣制取用时较笔者之前研究中以髌髁线为参考的传统方法制取股前外侧皮瓣用时少^[10]。

综上,混合现实技术应用于辅助股前外侧皮瓣穿支血管定位解可以作为一种术中导航穿支血管定位的新方法。然而其仍存在不足之处,如其校准的精确度有待提高,目前已有学者开始进行基于无校准点的校准算法研究;目前混合现实技术重建出的模型均为静态模型,随着手术的进行,当术区软组织发生形变时,混合现实重建模型不再与术区重合,无法为手术导航提供动态信息;此外,混合现实重叠于术区的虚拟模型对手术视野造成了一定遮挡,笔者认为应用混合现实技术将虚拟模型叠加在术区确定穿支点位置后,将模型移至术区旁作为解剖穿支血管的参考的模式更具临床应用价值。

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