

## 手外伤显微外科急诊处置流程优化专家共识(2025)

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**【摘要】** 对显微外科手外伤进行正确、规范的急诊处理非常关键,直接影响最终的治疗效果。本共识就显微外科手外伤的诊治范围、急诊处置的保障措施、急诊流程优化要点等相关问题,总结专家见解,提出规范化建议,供临床医生在实际救治过程中参考,以进一步提升显微外科手外伤的救治水平,最大限度地保护患者肢体功能与生活质量。

**【关键词】** 手外伤; 急诊处置流程; 显微外科技术; 专家共识

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手是一个具有复杂解剖结构的器官,对工作、交流、表达和日常生活至关重要,易受到意外伤害,且伤后若未及时正确诊治,可能导致手功能残障和患者心理问题<sup>[1-2]</sup>。早期正确处理合并血运障碍需要显微重建的手外伤非常关键,直接影响到最终的治疗效果<sup>[3]</sup>。此类急诊创伤对于伤情评估与诊疗分级、治疗决策、术前及术中准备,都对医疗机构及医务人员提出了巨大的挑战<sup>[4]</sup>。不管是在基层医疗单位还是三级医院,在急诊接诊流程方面都有很大的优化空间。流程的科学性不足与流程滞后浪费的时间,容易导致患者错过最佳救治时机;还有一些患者因为各种原因没有及时接受专科规范治疗,从而导致了手功能的不可逆的障碍,出现手部残疾等严重后果<sup>[5]</sup>。目前尚无全面、统一的急诊流程可供参考。为此,《中华显微外科杂志》编辑部在中华医学会显微外科学分会的指导下,由深圳市龙岗区骨科医院、郑州仁济医院和中山大学附属第一医院牵头撰写《手外伤显微外科急诊处置流程优化专家共识》,组织近20家单位的专家分别于2023年12月在武汉、2024年12月在西安召开2场现场研讨会,各位专家主要围绕手外伤后显微外科救治面临的相关问题进行充分讨论,形成本共识。其总结显微外科手外伤急诊就医流程的专家见解,围绕伴有手掌、手指离断或血运障碍手外伤患者的早期规范救治,对伤情评估、多中心(或上级)转诊、治疗决策、术前与术中准备等提出

规范化建议,以优化接诊流程、术前及术中准备,为需要应用显微外科技术进行血运重建及创面修复的手部创伤的救治过程提供参考,提高此类患者救治的规范性和效率,为患者提供优质的医疗服务,最大限度地保护肢体的功能与生活质量。

### 一、手外伤急诊需即刻手术处置的伤病类型

手外伤是指突发性的手部损伤,损伤范围以腕关节以远的腕掌及拇、手指损伤,致伤原因为切割伤、撕裂伤、挤压伤、撕脱伤等<sup>[6-7]</sup>。主要包括以下类型损伤:①手部血液循环障碍:包括指体完全离断、不全离断、指体大面积软组织撕脱伤及其它合并血管的损伤,影响指体血液循环,需要紧急进行血运重建,否则导致截指或指体坏死的严重手部创伤<sup>[8]</sup>;②指体血供不足、重要神经损伤:指体血液循环尚可但存在供血不足情况,如不修复血管,可能导致后期指体萎缩甚至部分坏死;指体感觉功能障碍,如不修复将严重影响功能;③指体血液循环不足或障碍同时合并大面积软组织缺损,需要急诊进行游离皮瓣修复<sup>[9]</sup>;④闭合性损伤引起血运障碍,因各种机械原因引起的闭合性血管损伤导致指体血运障碍,需紧急行血管探查修复;⑤其它:因感染导致的血运障碍、筋膜室综合征引起的血运障碍。

无血运障碍的手部创伤、指体毁损无再植条件、创面缺损行二期手术修复和指体功能重建等,不属于本共识范畴。

## 二、手外伤急诊处置的保障

1. 医护团队配置和资质: 处置手外伤的主诊医生应具备扎实的显微外科专业知识和丰富的临床经验, 能够准确判断损伤情况并制定合理的治疗方案。经过所在科室和医务部的考核, 能胜任手外伤的显微外科处置, 并获得相关资质。护理团队包括急诊室、手术室和显微外科病房, 应经过显微外科专业培训, 熟练掌握显微外科手外伤的围手术期处理和配合, 尤其是病房护理人员, 能够及时发现并处理血管危象等术后并发症。

2. 急诊值班制度: 为确保医疗安全和患者得到及时有效救治, 设立三线医生值班制度。一线医生一般为住院医师, 主要负责具体的患者管理和基本医疗处置; 二线医生通常是高年资主治医师, 对一线医生的工作进行指导和监督, 作为手外伤患者急诊手术的主刀医生; 三线医生为科主任, 在值班体系中起重要的指导和决策作用, 对于严重肢体创伤患者负责手术方案的制定并参与手术。

3. 大批伤员时的应急方案: 面对大批手外伤患者时, 医院应立即启动大规模伤员应急预案。包括以下几个方面: ①通知相关部门和人员, 包括急诊科、手外科、创伤骨科、手术室、麻醉科、检验科、血库等。②成立应急指挥小组: 由医院领导、科室负责人组成应急指挥小组, 负责统一指挥和协调救治工作, 确保救治工作高效有序进行。在急诊科设立伤员分类区, 由经验丰富的医生和护士对伤员进行快速分类。根据伤情严重程度分为危重伤、重伤、轻伤 3 类, 按照先救命、后治伤的原则, 优先救治危重伤员。③多台、多组手术同时进行: 在人员和设备允许的情况下, 可同时开展多台手术; 对于多发伤患者, 多组手术同时进行, 提高救治效率。安排经验丰富的手术团队负责危重伤员的手术, 确保手术质量和安全。④床位调配: 合理安排病房床位, 优先为危重伤员和重伤员提供床位, 可临时增设病床或调整病房布局, 满足救治需求。⑤物资调配: 检查和补充急救药品、医疗器械、血液制品等物资, 确保供应充足。必要时, 可向其他医院或上级部门请求支援。

4. 条件保障: ①手术显微镜: 高质量的手术显微镜是显微外科手外伤急诊处置的必备设备, 确保医生能够清晰地看到微小的血管和神经结构; ②手术器械: 配备齐全的显微外科手术器械, 如显微镊子、剪刀、持针器以及不同型号的血管夹、显微缝合线等; ③病房设施: 尽可能设有专门的显微外科手外伤病房, 保持适当的温度和湿度, 提供舒适的住院环境, 并且配备烤灯; ④制定完善的应急预案, 应对可能出现的术后出血、血管危象等需要紧急处理的情况。

## 三、手外伤急诊流程优化要点

1. 手外伤急诊伤情评估: 创伤的评估由急诊科医生及专科医生进行, 首先由接诊的急诊科医生进行初步评估, 如果患者有合并肢体血运障碍的创伤, 需要住院接受手术治疗, 则由住院部专科医师进一步评估。①全身评估: 对于车祸等损伤, 应遵循高级创伤生命支持(Advanced Trauma Life Support, ATLS)原则<sup>[10]</sup>。重点在于发现并抢救重要器官的严重损伤、隐匿损伤和威胁生命的损伤(先救命, 后保肢)<sup>[7,11-12]</sup>; 对高龄或全身状态差的患者(如严重心血管系统疾病、呼吸功能不全、凝血功能障碍等)处置要慎重。②专科查体评估: 针对手外伤患者的初期评价, 应注意软组织损伤(有外观照片)、血管损伤、神经损伤、骨筋膜室综合征、骨折粉碎程度(进行放射影像学检查)等, 一定要记录在案, 并与伤者家属沟通, 交代伤情与预后。

基于数码照片的诊断准确性的信息, 手外科医生应与急诊科医生多交流、沟通, 不断改进、完善, 以便急诊科医生熟练掌握手外科医生希望捕捉到的手外伤照片细节<sup>[5]</sup>。专科检查主要针对循环、感觉和运动功能评估, 包括以下几方面: 肢体血液循环(皮肤颜色、张力、皮温、毛细血管反应)、神经功能(相应神经支配区域的运动、感觉)、肢体解剖关系(局部畸形、异常活动、开放性伤口及伤口出血、污染程度、软组织缺损等)。如怀疑有骨折或脱位应进行 X 线检查, 对于离断肢体同样需要拍摄 X 线片, 以了解骨折情况<sup>[13]</sup>。由于严重的疼痛、畸形或患者的担心, 存在患者配合度不足的情况<sup>[14-15]</sup>。X 线检查可能会遗漏骨折或脱位, 必要时麻醉后在手术台上重复进行 X 线检查。

2. 资源共享, 必要时实现快速转诊: 因为区域医疗资源不平衡、三级医院床位或者手术室资源的限制, 很多患者不能第一时间到具备显微外科技术的医院进行救治, 而是需要转诊到合适的医院进行急诊手术<sup>[16-17]</sup>。适当的初步管理是取得良好效果的关键因素。患者到达急诊室后应了解处理措施是否得当, 对伤口进行包扎是避免出血的重要措施。而对断指的正确保存可减少热缺血的时间, 长时间的热缺血已被证明会对再植成活率产生影响<sup>[18]</sup>。离断的指体或组织块清洗后应立即用干纱布包裹, 置于塑胶袋并标记热缺血时间及患者姓名, 放入冰箱冷藏(4℃~6℃)<sup>[19-21]</sup>。

完善的初始治疗可以直接影响手的最终功能, 医疗机构接急诊后应快速准确地评估伤情, 如经评估所在单位无诊治条件, 特别在急需显微外科专科治疗的情况下, 应及时转诊到医疗设施更好、医务人员更专业的医疗机构, 以期提供更好的救治, 避免延误最佳治疗时机<sup>[1,22]</sup>。转诊前与接收的手外科协调与沟通, 确保转诊后第一时间得到专科治疗, 同时对转诊患者确保相





关检查结果随人员携带,特别对于断指、断肢要在有正确保存的前提下转送<sup>[22]</sup>。

### 3. 快速启动手术流程,减少热缺血时间

(1) 急诊科一站式完成术前准备及手术计划:对于需急诊进行血运重建的患者,目前多数医院接诊手外科急诊创伤患者的流程相对滞后,患者由急诊科医生进行初步的评估和检查后,再办理住院到相应的科室进行术前准备,过程较为繁琐、耗时<sup>[23]</sup>。为提高诊治效率,住院部专科医生到急诊科进行各种术前检查、签署各种医疗文书,完善术前准备后将患者直接转运至手术室,可有效减少中间环节,缩短术前准备时间<sup>[19]</sup>。专科医师接诊流程的前置,对于专科医院容易做到;而对于综合医院,特别是大型的三级医院,涉及到医院的空间(如住院部到急诊科的距离)、急诊科的配套实施(医务人员、医疗用房等)等,对方案的实施可能较为困难<sup>[24]</sup>。针对危及生命的严重创伤及多肢(或指)离断,应快速启动绿色通道,急诊科医师负责在急诊科期间的生命监测,同时通知相应科室参与会诊和抢救<sup>[25]</sup>。患者进行术前检查后,由急诊科直接送入手术室。

高效利用时间对于伴有血运障碍的肢体创伤患者至关重要,快速的血液循环重建,可减少术后并发症。应充分利用患者到达手术室完成麻醉之前的时间,接诊患者后将离断肢体带入手术室进行清创并将血管、神经及肌腱进行标记;针对多平面离断的肢体,清创后可先进行远平面离断的再植。多组医务人员同时或轮换进行手术对于多肢、多指损伤的患者可缩短手术时间,避免医务人员疲劳手术,减少术中的不良事件发生,保障手术的高质量完成。

(2) 规范、严格、彻底的开放性清创:针对显微外科手外伤患者充分的早期清创对减少感染风险、保全指体、恢复肢体功能具有重大意义<sup>[26]</sup>。清创不彻底可能增加感染风险导致再植组织坏死,影响疗效及预后。对于完全离断伤,明确手术方案后,在完善术前准备的同时,提前进入手术室对离断肢(或指)体进行清创及血管、神经、肌腱的探查和标记<sup>[26-29]</sup>,有利于尽快恢复肢体血运,减少热缺血时间<sup>[13,30]</sup>。手部解剖结构复杂而精细,应用止血带可提供清晰的术野<sup>[31]</sup>,对软组织、肌腱和骨质清创时推荐在放大镜(2.0~3.5 倍)下进行,而血管、神经应该在显微镜(8.0~15.0 倍)下进行清创,适当扩大创口,根据解剖层次由浅到深地进行地毯式清创。同时仔细检查神经、血管、肌腱和骨骼的受损情况,对于严重污染、挫伤及无血运的组织应彻底清除,清创结束后应用足量生理盐水进行冲洗。

(3) 发挥显微外科技术优势,高质量修复重建损伤组织:手外伤患者的修复与重建,术者应充分评估损伤

情况与术后可能获得的功能和外形,最好的手术治疗是血运重建或再植。对于特别严重的肢体损伤,经评估修复后预期可用的功能和可接受的美学效果时,应尽可能寻求重建,因为严重受限的肢体的保留通常优于人工假体的功能。而针对肢体毁损、创面存留或再植术后坏死的修复和重建方式的选择,应根据手部各个区域的功能解剖特点,遵循“组织结构相似性”的修复原则<sup>[32]</sup>。复合性损伤包括骨、关节和软组织大面积缺损,在保肢手术过程中还要重点做好“清创彻底、血管重建、骨折稳定”。根据伤情建议采用以下手术技巧与手术方案:①采用“三、四定点褥式外翻”连续血管吻合方法<sup>[33]</sup>,该吻合法保持血管壁外翻,避免了血管管壁内翻,防止外膜进入血管腔,避免血管缩窄,通过定点缝合中间加针使针距一致,防止漏血,克服了单纯间断缝合存在的不足,可使血管壁更光滑,血管通畅率增高,能降低血管痉挛和栓塞率,通过高质量血管吻合,修复至少一组动、静脉主干,并进行良好软组织覆盖,可靠恢复肢体血液循环,保证肢体先成活,为后期功能重建奠定基础。②结合损伤控制理念,针对骨折可采用内、外结合分步组合固定法,先简单内(单边外)固定,不影响显微再植修复手术操作;再微创增补穿针组合外固定,弥补简单固定不牢的缺点;再植后期结合治疗需要再通过穿针组合灵活调整。③不过多考虑肢体长度,一期缩短再植,先保成活,二期应用 Ilizarov 技术进行肢体矫形延长功能重建,减少手术创伤、降低手术风险。根据缺损区域的功能与外形需求设计不同的皮瓣,匹配供、受区部位的颜色、质地及功能特点。使用游离皮瓣重建手部软组织缺损有许多的优点,可以根据缺损区域的功能与外形需求设计不同的皮瓣,携带长血管蒂的皮瓣允许在损伤区外进行血管吻合。各种组织瓣的组合移植可重建严重的手部损伤,获得基本的手部功能。足趾组织瓣及足底内侧皮瓣修复手掌和手指等关键部位,重建后可获得耐磨性好、感觉良好、无毛发生长、有皮纹和指甲的良好功能和外形。股前外侧皮瓣、髂腹股沟皮瓣、腓动脉穿支皮瓣可切取面积大,可应用于大面积的软组织缺损。

(4) 多学科会诊与手术室资源的优化:显微手外科的急诊救治面临科间协作问题,首先是对于合并伤、危及生命的患者需要多学科团队(Multidisciplinary team, MDT)的参与抢救,遵循先保命再保肢的原则,此时麻醉科医生应提前参与伤情评估,针对手术方案做好麻醉决策,为患者生命提供保障<sup>[34-36]</sup>。在保障生命安全的前提下,根据肢体损伤程度决定手术方案。医疗单位应建立相关制度及急诊绿色通道,保障严重肢体损伤及合并多发伤患者救治流程顺畅。

(5)伴有多发伤的严重肢体损伤的救治:结合仁济经验<sup>[37]</sup>,在救治伴有多发伤的严重肢体损伤时通过成立“大肢体离断救治中心”,优化会诊、急救流程,改进手术技术,形成科学、合理的救治流程和体系,完成了伴有头、胸、腹多发伤的严重肢体损伤和孕期肢体严重创伤复杂案例的成功保肢<sup>[38-39]</sup>。该中心由骨科、胸外科、普外科、影像科、神经外科、泌尿外科、妇产科、急诊科、重症科、显微外科等各科主任、专家组成多学科、多技术协作团队,同时检验科、输血科全力配合,建立相应的管理制度和运作流程,提高多学科协作的效率和水平;坚持“抢救生命,积极保肢或果断截肢,防治感染并发症,后期功能重建恢复功能”的救治策略;遵循“争分夺秒、减少出血与创伤、尽可能缩短保肢手术时间”原则。

首先,通过多发伤的科学评估确定是否保肢:结合简明损伤评分(Abbreviated Injury Scale, AIS)-创伤严重程度评分(Injury Severity Score, ISS)、Mangled 肢体创伤严重程度评分(Mangled Extremity Severity Score, MESS)及顾立强等<sup>[40]</sup>改良 Gustilo 分型评估标准判断是否保肢。其次,综合以下条件选择是否保肢:①头、胸、腹部创伤危急重症已处理,生命体征稳定;②ISS 小于 20 分;③MESS 小于 10 分;④改良 Gustilo III D 型以内有具备保肢条件;⑤血红蛋白、红细胞、血小板等在危急值以上、有充足的血源备用,评估预后肢体功能要优于假肢,患者保肢意愿强烈,经济条件允许,术后无因保肢引起危及生命的严重并发症的发展趋势。第三,建立显微外科 MDT 四步动态诊疗评估保肢模式:初次评估肢体毁损严重、无保肢条件时果断截肢;初次评估肢体有保肢条件时启动“四步动态诊疗评估保肢模式”:即院前评估、院内抢救后评估及头、胸、腹重症手术急救后评估和保肢术后管理评估,不错过每一个保肢机会。

在救治策略方面,对 ISS 大于 16 分的患者,启动急诊绿色通道,快速稳定生命体征并处理头、胸、腹部危急重症,MDT 共同参与会诊救治,边抢救、边检查、边诊断、边评估;争取 30 min 内完成术前准备工作。

(6)力争一期创面修复,为手功能快速康复创造条件:一期修复被认为有利于手功能的恢复,并避免二次手术,同时可以早期功能锻炼,利于手功能恢复。但急诊修

复可能导致人力资源的紧缺,同时医务人员疲劳手术可能导致不良事件的增加。基于此,针对合并肢(指)体血运障碍的软组织缺损,且缺损部位有神经、血管外露,特别是重建的动脉及静脉需要一期应用软组织覆盖创面,要保证组织的良好血液供应<sup>[41-43]</sup>。对于未合并血运障碍的软组织缺损,创面可临时利用伤口负压治疗技术(Negative pressure wound therapy, NPWT)、骨水泥等覆盖,伤后 3~5 d 再进行组织缺损的修复和重建<sup>[44-45]</sup>。

#### 四、共识实施的建议

通过优化显微外科手外伤急诊手术早期救治流程,减少患者就诊时间和术前检查等待时间,提高急诊手术效率和质量,为患者提供优质的医疗服务,最大限度地保护肢体功能;同时各医院应在专科转诊、MDT 配备等方面进行必要优化,提高手外科急诊救治水平。

实施本共识需要全体医务人员的共同努力,医疗单位间的层面应建立区域转诊体系,确保显微手外伤患者的转诊高效进行。医院内部应加强科室间的联系,建立顺畅的衔接机制,保障急诊患者早期救治流程的有效实施。此外,通过案例交流与专业培训,进一步提高医务人员的技术水平与诊治能力,为患者提供更优质的医疗服务。

**免责声明** 本共识根据手外伤显微外科急诊手术早期救治的特点和需求,结合临床经验与最新医学研究,旨在为临床实践提供参考,仅供同行参阅及专科医师作为显微外科、创伤骨科、修复重建外科等专业的技术参考,不能将其作为绝对标准,更不作为法律依据,不具备法律效力,不作为任何医疗纠纷处理选择的法律法规依据。其中的原则也是灵活的,而且,本共识具有时限性,随时根据科学研究和临床实践的发展进行更新与完善,并会随着将来有更高级更充分研究证据和理论的出现而更新修改。

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## • Expert Consensus •

## Expert Consensus on Optimisation of Emergency Management Procedure for Hand Injury in Microsurgery (2025)

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**[Abstract]** Standardised emergency management protocols for hand injury in microsurgery is critical, as it directly determines ultimate clinical outcomes. This consensus consolidates expert insights regarding diagnostic and treatment procedure for hand injury in microsurgery, emergency support protocols and key points of emergency workflow optimisation. It summarises the opinions of experts and puts forward standardised recommendations to guide clinical practice in microsurgical treatment process, so as to further improve the quality of treatment for hand injury in microsurgery and maximise the protection of limb function and quality of life of patients.

**[Key words]** Hand injury; Emergency management protocols; Microsurgical techniques; Expert consensus

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Hand is an organ with complex anatomical structures and is essential for work, communication, expression and daily life. However, it is prone to accidental injuries, and an untimely or improper diagnosis and treatment may lead to impairment of hand function and psychological issues<sup>[1-2]</sup>. An early and proper treatment of hand injury with blood supply disorders that require microsurgical reconstruction is critical, as it directly affects a surgical outcome<sup>[3]</sup>. For such an emergency hand injury, injury assessment, triage stratification, surgical plan formulation, and pre- and intra-operative preparation pose

significant challenges to hospitals as well as the surgeons<sup>[4]</sup>. Moreover, there are plenty of rooms for optimisation in both primary clinics and Tier-III hospitals in emergency admission protocols. Consequently, an insufficient scientific protocol and a delay due to poor process protocols may lead the patients to miss the optimal treatment window, while some patients may face consequences of irreversible functional impairments of hand or disability due to delays in specialised treatment<sup>[5]</sup>. Currently, there is no comprehensive, standardised emergency procedure available for reference. To address this drawback,



under the guidance of the Chinese Society of Microsurgery, the Editorial Board of *Chinese Journal of Microsurgery* commissioned Shenzhen Longgang Orthopaedic Hospital, Zhengzhou Renji Hospital and the First Affiliated Hospital of Sun Yat-sen University jointly drafted this *Expert Consensus on Optimisation of Emergency Management Procedure for Hand Injury in Microsurgery*. Subsequently, 2 seminars were organised in Wuhan (December 2023) and Xi'an (December 2024) with experts from 20 hospitals for the purpose. The experts thoroughly debated and discussed challenges in microsurgical treatment in hand injury and concluded this consensus. This consensus summarises the expert opinions on the emergency procedures in treatment of hand injury with microsurgery, and puts forward standardised recommendations on injury assessment, multi-centre (or superior hospital) referral, formulation of treatment plan, preoperative and intraoperative preparation around the early standardised treatment of the patients and hand injury with traumatic metacarpal and digital amputations and(or) with blood supply disorders, thereby to optimise the emergency procedure, preoperative and intraoperative preparation. It provides a reference for the treatment of hand injury that requires microsurgical revascularisation and wound reconstruction. The overarching goal of this consensus is to improve the standardisation and efficiency in treatment of the patients with hand injury, deliver high-quality medical services and maximise the preservation of limb function and quality of life of the patients.

### I . Type of hand injury that requires immediate surgical treatment in an emergency department

Hand injuries that require microsurgical treatment refer to acute and traumatic injuries involving hand structures between the wrist and distal digit, including carpometacarpal region, thumb and fingers. Typically, injury mechanisms include laceration, avulsion, crush and degloving injury<sup>[6-7]</sup>. Specifically, major injuries require urgent microsurgical treatment: (1) Vascular compromise in complete/incomplete traumatic digital amputation, extensive soft tissue avulsion, or other vascular injury that compromise blood perfusion and require emergent revascularisation to prevent necrosis or amputation<sup>[8]</sup>. (2) Insufficient blood perfusion with critical nerve injury, such as a fair limb blood circulation but with insufficient blood supply at the injury site, of which an unreconstructed blood vessel may lead to partial necrosis or even hand atrophy in later stage; a sensory dysfunction of which an untreated nerve injury may lead to significant functional impairment. (3) In a case of insufficient or impaired blood circulation with extensive soft tissue defect, an emergency treatment with free flap transfer is required<sup>[9]</sup>. (4) Insufficient or impaired blood circulation with closed injury: a closed vascular injury caused by mechanical impact may lead to blood supply disorders around the injury site, which requires emergency vascular exploration and reconstructive surgery. (5) Other types of blood supply disorder: insufficient blood circulation or an ischemia may be caused by infection or compartment syndrome.

Where, following are not fallen within this consensus: a hand

injury without a blood supply disorder, a severe mangled hand impossible for replantation, a defect being planned for stage-II reconstructive surgery, and reconstruction of hand function.

### II . Support and emergency management in hand injury

1. Surgical team and qualifications: In treatment and handling of a hand injury, the attending surgeon must have solid microsurgical expertise with excellent clinical experience, and is able to make accurate judgement about the injury and quickly formulate a reasonable treatment plan. He/she must be accessed by the department and medical administration office of hospital for necessary and formal credentials, and is competent to carry out the treatment for hand injury with microsurgery techniques. Meanwhile, the nursing teams, including A&E (Accident & Emergency) department, operating theatre and microsurgery ward, are equally important. The nursing teams in various departments should be trained with microsurgery and be proficient in perioperative nursing and team collaboration, especially the ward nursing staff must be able to observe and handle postoperative complications such as vascular compromise in time.

2. Emergency duty system: A three-tier emergency duty system must be in place to ensure patient safety and a prompt and effective treatment. A Tier-1 surgeon (resident) is responsible for essential patient management and primary treatment. A Tier-2 surgeon (senior registrar) takes responsibilities to guide and supervise Tier-1 surgeons, and serves as the chief surgeon in emergency microsurgery in treatment of hand injury. Where is a Tier-3 surgeon (consultant) takes responsibilities to provide strategic guidance, make critical decisions, formulate surgical plans and participate in emergency surgery for a severe hand injury.

3. Response protocol for mass casualty in emergency microsurgery: In an emergency situation with large number of casualties with hand injury, a hospital must promptly activate the mass casualty protocols to handle mass cases of hand injury following microsurgical procedures. The protocol should include following key measurements: (1) Immediately inform and mobilise multidisciplinary departments of A&E (Accident and Emergency), Hand Surgery/Microsurgery, Orthopaedics & Trauma, Operating Theatre, Anaesthesiology, Medical Laboratory and Blood Bank. (2) Assembly a collaboration centre led by major hospital administrators and directors of departments to establish an emergency commanding team, which is responsible for unified commanding and coordination of the emergency process to ensure efficient and orderly streamlined treatment. A casualty triage zone must be immediately set up in A&E department, where experienced doctors and nurses should quickly triage the casualties. According to the severity of an injury, 3 categories are established to triage casualties: critical, serious and minor injury. Apply the rule of "Life prior to limb", priority should be given to the critically injured patients. (3) Organise multiple surgical teams for multiple surgery: execute parallel surgeries when resources permit; For patients with multiple injuries, multiple groups of surgery should be performed at

the same time to improve the efficiency of treatment. Arrange an experienced surgical team to perform the surgery for critically injured patients to ensure the quality and safety of the surgery. (4) Ward and bed allocation: management of ward and beds, offer beds to the critically and seriously injured patients. Additional beds should be temporarily added or ward floor should be re-planned to meet the emergency situation. (5) Management of medical resources: check and stock critical medical supplies (medications, instruments, blood products, etc.), seek external support and backup whenever it is necessary.

4. Critical facilities: The essential items include: (1) High-quality surgical microscope. It is a must equipment to enable surgeons clearly see tiny blood vessels and nerves in emergency hand microsurgery. (2) Specific instruments for microsurgery: complete sets or the instruments for microsurgery including micro-forceps, micro-scissors in various specifications, needle holders, vascular clips and micro-sutures. (3) Ward facility: with the best efforts to set up a ward with the specifications for hand surgery/microsurgery that facilitates with an appropriate temperature and humidity, equips with infrared thermal lamps and provides a comfortable hospital environment. (4) Contingency plans: contingency plans must in place to deal with possible postoperative events such as bleeding, vascular compromise and other unforeseen situations that require emergency treatment.

### III. Critical issues in optimisation of emergency procedures for hand Injury

1. Diagnostic evaluation in hand injury: Injury assessment should be conducted jointly with emergency doctors and specialists, with initial assessment performed by the attending emergency doctor. Notably, if the injury involves blood perfusion disorder of a limb, hospital admission and surgical intervention are required. Further examinations must be taken by the specialist. (1) A systemic evaluation: specifically for an injury involved in traffic accident, ATLS (Advanced Trauma Life Support) procedure should be followed<sup>[10]</sup>. The focus is to explore and rescue serious, hidden and life-threatening injuries of vital organs (Life prior to limb)<sup>[7,11-12]</sup>. Cautions must be paid to the treatment of elderly patient or the patient with poor general condition, such as severe cardiovascular disease, respiratory insufficiency, coagulopathy, etc. (2) Physical examination and assessment by specialist surgeon: following must be documented in the initial specialist evaluation of a hand injury: soft tissue injuries (by photos and document), injury of blood vessel and nerve, compartment syndrome and comminuted fractures (by medical imaging). All findings must be documented and clearly go through with the family members of patient with clear notification of severity and prognosis of the injury.

Hand surgeons and emergency doctors should collaborate closely through ongoing communications, through the photos of hand injury taken by a camera, to improve and refine diagnostic accuracy,

and enable emergency doctors to pin point the details of hand injury that a hand surgeon wants to know<sup>[5]</sup>.

Specialist examinations must thoroughly check circulation, sensation and motor functions of the injured limb, including: blood perfusion (skin colour, turgor, temperature, capillary refill, etc.), nerve status (motor/sensory function through innervated zones), anatomic integrity (deformity, abnormal mobility, open wound with bleeding/contamination, soft tissue defect, etc.). X-ray should be taken if a fracture or dislocation is suspected. X-ray should also be taken for traumatically amputated limbs to evaluate fractures<sup>[13]</sup>. In clinical practice, limited patient cooperation is expected due to severe pain, fracture or anxiety<sup>[14-15]</sup>. Preoperative X-rays may miss out fractures/dislocations, therefore it is necessary to re-take X-rays under anaesthesia in surgery.

2. Sharing medical resources and timely patient referral when necessary: In real world, due to limited medical resources in local hospitals or limited beds and limited capability in operating theatre in a Tier-III hospital, under emergency situations, many patients are not primarily sent to a hospital that has microsurgical capability and facility. Therefore, the patients should be transferred without delay, to a hospital with appropriate capabilities for emergency treatment<sup>[16-17]</sup>. Proper initial injury management is a key factor in achieving good results. As soon as the patient arrives in hospital, emergency doctor should know what treatment measures are appropriate. Wound dressing is an essential measure for haemorrhage control. Proper preservation of the severed digits can reduce the time of warm ischemia, as a prolonged warm ischemia affects the survival rate of digital replantation<sup>[18]</sup>. A severed digital body or tissue block should be wrapped with dry gauze immediately after cleaning and has it placed in a plastic bag, labelled with the time of warm ischemia and the name of patient, then has it stored under refrigeration or in a refrigerator at 4 °C–6 °C<sup>[19-21]</sup>.

A proper primary treatment directly determines ultimate function of the hand. The injury of hand should promptly and accurately assessed after emergency treatment. In the case that there is no condition for diagnosis and treatment in a local hospital, especially in the case of urgent requirement for specialist microsurgical treatment, the patient should be immediately transferred to a hospital with better medical facilities and specialist surgeons in microsurgery for better treatment in time to avoid a delay of the best treatment<sup>[1,22]</sup>. Coordinate and communicate with the receiving hand surgery department before transfer of patient to ensure that specialist treatment is available immediately after patient arrival. Make sure all diagnostic records must be accompanied with the patient transfer, and the severed digits and limbs must be under proper preservation in transport<sup>[22]</sup>.

3. Expedite surgical procedures on patient arrival to minimise warm ischemia time

(1) Complete preoperative preparation and surgical plan though fast track procedure in an A&E department. However, current admission process in most hospitals for a patient with hand injury is



relatively slow; specifically there is an obvious delay of treatment after initial assessment and examination at A&E department: a cumbersome and time-consuming admission process is followed first by transferring the patient to a relevant department for preoperative preparation on a patient who requires an immediate surgery to reconstruct blood vessels<sup>[23]</sup>. In order to improve the efficiency of diagnosis and treatment, specialist surgeons of relevant specialised ward should be on-site in the A&E department to facilitate completion of various preoperative examinations and medical documents, then transfer the patient directly to operating theatre after a preoperative preparation. To do so will effectively reduce the steps of process and minimise the time for preoperative preparation<sup>[19]</sup>. Forward deployment of specialist consultation is an easy and achievable task in specialised hospitals, however it could be a difficult task in a general hospital, especially a large Tier-III hospital, where a large territory of hospital (e.g., the distance between emergency department and inpatient department) and available facilities of the A&E department (e.g. medical staff, treatment rooms, etc.) may pose difficulties to implement an emergency surgery<sup>[24]</sup>. For life-threatening severe injury and multiple traumatic amputation of limbs/digits, the fast-track procedure should be activated rapidly, and the doctors in A&E department are responsible for life monitoring during the patient's stay in the A&E department while simultaneously notifying relevant departments for consultation and life-saving<sup>[25]</sup>. Ultimately, the patient should be directly sent to the operating theatre from an A&E department.

Efficient time management is crucial for patient with limb injury and complicated with blood supply disorders. A rapid restoration of blood circulation can reduce postoperative complications. The time window before a patient arrives in the operating theatre and completion of anaesthesia should be fully utilised by taking the severed hand to operating theatre for debridement and markings of blood vessels, nerves and tendons. For multi-plane amputations, replantation should start from the most distal-plane after debridement. It is necessary to mobilise multiple microsurgical teams to perform the surgery at same time or in rotation in the treatment of a patient with multiple limb and digital injuries. This will cut down surgical time, avoid tiredness of a medical team, reduce intraoperative adverse events and ensure high quality completion of the surgery.

(2) Standardised, strict and thorough debridement for open injuries: An adequate early debridement for traumatic hand injury is of great significance in reducing risk of infection, preserving the digit, and restoring limb function<sup>[26]</sup>. However, an inadequate debridement may increase a risk of infection, cause necrosis of replanted tissue and affect therapeutic efficacy and outcomes. For a complete amputation, after the surgical plan has been confirmed, surgical teams should enter the operating theatre in advance to carry out debridement of the severed limb/digits and exploration and marking of blood vessels, nerves and tendons while the patient is under a preoperative preparation<sup>[26-29]</sup>. This strategy facilitates a rapid restoration of limb

blood supply and reduces warm ischemia time<sup>[13,30]</sup>. Considering the complex and delicate anatomy of hand, tourniquet should be applied to achieve a clear surgical field<sup>[31]</sup>. For optimal results, it is suggested to perform debridement of skin, soft tissue, tendons and bone under surgical loupes (2.0–3.5× magnification), while debridement of vessels and nerves should be performed under a surgical microscope (8.0–15.0 × magnification). During this process, surgeons should appropriately extend the wound and perform a carpet-debriding layer-by-layer from surface to depth according to anatomical planes. Concurrently, carefully explore damages of nerve, vessel, tendon and bone. For the tissues with heavy contamination, badly crashed tissues and tissues without blood supply should be radically and thoroughly removed, followed by a flush with sufficient saline after debridement.

(3) Apply the advantages of microsurgical techniques to achieve high-quality reconstruction of defected tissues. Surgeons must comprehensively evaluate the extent of injury, achievable postoperative function and aesthetic outcomes in treatment of a hand injury. However, an optimal surgical treatment is revascularisation or replantation. For an extremely mangled injury, reconstruction should be pursued as best as possible after evaluation of the expected function and acceptable aesthetic outcomes after surgical treatment, based on the fact that an impaired limb is often superior to the function of an artificial prosthesis. The principle of a "like-for-like reconstruction" should be followed according to functional anatomical characteristics in per affected area of hand in the treatment of a mangled injury, residual wound or postoperative tissue necrosis<sup>[32]</sup>. In a limb salvage surgery, it should focus on thorough debridement, vascular reconstruction and fracture fixation when handling a complex injury includes large defects of bone, joint, skin and soft tissue. According to an injury, following improved surgical techniques and procedures are recommended: (1) Apply three(or four)-point mattress valvulus anastomosis for continuous vascular anastomosis<sup>[33]</sup>. This suturing technique keeps the vascular wall eversion, prevents the vascular wall from eversion, prevents the adventitia from entering the blood vessel, avoids the narrowing of the blood vessel, ensures consistent stitch spacing by adding a stitch in the middle of fixed-point suture to prevent blood leakage, overcomes the defect of simple intermittent suture, ensures a smooth vascular wall, increases the vascular patency rate hence reduces the vasospasm and embolism rate. Restore at least 1 group of arterial and venous trunks with high-quality anastomosis, then make good soft tissue coverage, restore reliable blood circulation to ensure the survival of limb for later functional reconstruction. (2) Under principles of damage control, employ staged hybrid fixation for fractures: initially, apply a minimal internal/external fixation to avoid interference to the microsurgical procedure, followed by percutaneous external fixation with Kirschner wires to make up for the shortcomings of simple fixation. In the later stage of replantation, flexible combination of Kirschner wires shall be adjusted according to the treatment. (3) To ensure survival of the replanted limb, length of the affected limb can be temperately shortened in pri-

mary replantation surgery. While in stage-II surgery, apply Ilizarov technique to restore the length and function of the limb meanwhile minimise damages and risks of surgery. Design flaps according to function and appearance of the defect sites and match the colour, texture and function of the donor and recipient sites. There are many advantages in free flaps to reconstruct soft tissue defects of hand. A flap with a long vascular pedicle allows vascular anastomosis beyond an injury site. Transfer of combined flaps of various types of tissue can reconstruct severe hand injury and restore essential hand function. For example, a toe-derived flap and a medial plantar flap are ideal for critical areas (palm/digits), with durable, sensate, hairless reconstruction with skin creases and nail for optimal function and aesthetics. Large soft tissue defects can be reconstructed by the flaps in large size such as anterolateral thigh flap (ALTF), groin flap and peroneal artery perforator flap.

(4) Multidisciplinary team consultation and optimisation of operating theatre resources: In practice of microsurgery, inter-department collaboration is the primary issue faced in emergency treatment of hand microsurgery. First of all, for a patient with combined multiple injury with life-threatening conditions, a multidisciplinary team (MDT) from relevant hospital departments must be called upon to participate in the patient rescue following the principle of "Life prior to limb". Meanwhile, anaesthetists should engage the injury assessment in advance and formulate anaesthetic strategies aligned with surgical plans, as well as to ensure the patient safety<sup>[34-36]</sup>. On the premise of ensuring the safety of life, definitive surgical approaches should be determined according to the severity of upper extremity injury. Hospitals should establish standardised protocols and emergency green channels to ensure smooth and seamless treatment process of a patient with severe upper extremity injury and with combined multiple injuries.

(5) Treatment of severe upper extremity injury with multiple injuries: Refer the experiences of Renji Hospital<sup>[37]</sup> in treatment of severe limb injury complicated with multiple injuries, consultation and an emergency treatment process is optimised through the establishment of a "Treatment Centre for Major Limb Traumatic Amputation", and surgical techniques are optimised, a scientific and reasonable treatment procedure and system are formulated. It helps successful cases in salvage surgery for severe limb injury with multiple injuries of head, chest and abdomen and a case of severe limb injury in pregnancy<sup>[38-39]</sup>. The centre teams up a multi-disciplinary and multi-technical collaboration team with departmental directors and medical experts from orthopaedics, thoracic surgery, general surgery, medical imaging, neurosurgery, urology, obstetrics and gynaecology, emergency, critical care, microsurgery, other hospital departments and with fully support from medical laboratory and blood bank, a corresponding management system and operation process are established to improve the efficiency of multi-disciplinary collaboration. The centre adheres to the treatment strategy of saving lives, actively limb salvage or decisively limb amputation to prevent and treat in-

fections and complications first, then reconstructing and restoring functions in later stage. These efforts follow the principles of "Work against time; minimise bleeding and iatrogenic damage; shorten limb salvage surgical time whenever feasible".

First of all, through the scientific assessment of multiple injuries with AIS-ISS (Abbreviated Injury Scale, Injury Severity Score), Mangled Extremity Severity Score (MESS) and modified Gustilo classification by Gu Liqiang et al.<sup>[40]</sup>, to determine whether a limb salvage is feasible. Followings are criteria in determination of limb salvage: (1) A stabilised life-threatening head/thoracic/abdominal injury with stable vital signs; (2) ISS score < 20; (3) MESS score < 10 for limb injury; (4) Salvageable limb within modified Gustilo Type III D; (5) Haemoglobin/erythrocyte/platelet above critical thresholds with adequate blood reserve on site of hospital. Additionally, overall assessment concludes that a salvaged limb function surpassing prosthetics, strong patient preference for salvage, financial feasibility and without postoperative life-threatening complications after limb salvage surgery. Establish a four-step microsurgery MDT dynamic assessment model for limb salvage: decisive amputation after an initial assessment of a severely injured limb confirms impossible for limb salvage. Start the four-step dynamic assessment model for limb salvage while an initial assessment of a severely injured limb shows a feasible limb salvage. The four-steps are: pre-hospital assessment, in-hospital assessment after life-rescue, assessment after emergency surgery for severe head, chest and abdominal injury, and assessment of postoperative management of limb salvage. Make sure no possible opportunity for limb salvage is missed.

Regarding the aspect of limb salvage strategy, if ISS score > 16, an emergency green channel shall be immediately triggered, vital signs of patient should be stabilised quickly and in the critical and severe case with a head, chest and abdominal injury, they must be treated promptly, meanwhile a MDT consultation and treatment must be started. While during the process of patient life-rescuing, the tasks of examination, diagnosis, evaluation and preoperative preparation shall all be completed within a 30 minutes time window.

(6) Achieve primary reconstruction for expedited recovery of hand function: Primary reconstruction is considered beneficial to a recovery of hand function and avoid secondary surgery, meanwhile an early functional exercise will benefit a recovery of hand function. However, an emergency surgery may face a shortage of medical staff, and a tiredness of medical staff may lead to an increase in adverse events. Therefore, for a soft tissue defect with disorder of limb (or digital) blood supply, and a defect site with exposed nerves and blood vessels, especially the wound with reconstructed arteries and veins, the defect should be covered by soft tissue in primary surgery to ensure good blood supply to the tissue<sup>[41-43]</sup>. For a soft tissue defect without blood supply disorder, the defect can be temporarily managed negative pressure wound therapy (NPWT) or bone cement, and leave the soft tissue defect to be reconstructed at 3-5 days after injury<sup>[44-45]</sup>.



#### IV. Recommendations for implementation of this consensus

By optimising an early treatment protocols of emergency micro-surgery for hand injury, the time for patients to see a specialist can be sped up hence the waiting time for preoperative examinations is reduced, the efficiency and quality of emergency surgery are improved, high-quality emergency services are provided for patients, thereby limb functions could be preserved to the maximum extent. Moreover, hospitals must make necessary optimisation in specialist referral and MDT collaboration to improve emergency treatment in an event of receiving a patient with severe hand injury.

Implementation of this consensus requires intensively collaborating efforts of all medical staff. A regional patient referral system should be established between local hospitals to ensure an efficient referral of patients with hand injury. A hospital should strengthen the connection between departments, establish a smooth collaboration system to ensure an effective implementation of early treatment process for emergency patients. In addition, further improvements of skills, diagnosis and treatment capability of medical staff are necessary for better medical services through case-based communications and professional trainings.

**Statement** This consensus is formulated according to the characteristics and requirements of early treatment in emergency surgery. It combines clinical experiences with the latest medical research,

and aims to provide a reference for clinical practice. It is exclusively for peer consultation and as a technical guide for specialists in micro-surgery, orthopaedic trauma, and reconstructive surgery. It is hereby noted that this document does not constitute absolute standards, nor serves as legal basis or possess legal validity, nor is referenced in medical dispute or medico-legal proceedings. The principles herein are deliberately flexible, and this consensus remains time-efficient-subjects to continuous refinement based on evolving scientific research and clinical experience. It will undergo scheduled revisions as higher-grade evidence and advanced theoretical frameworks emerge.

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