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The Impact of Anesthesia and Surgical Exposure on Quadriceps Muscle Function

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Abstract

Quadriceps strength (QS) may be reduced one year after total knee arthroplasty (TKA) interfering with activities of daily living. Impairments of quadriceps motor function also represent the true limit to complete all functional tests leading to a lower Knee Society Functional Score.Both anesthesia techniques and surgical exposure can affect short-term outcome but there is a lack of evidence that regional anesthesia techniques as well as mininvasive approaches also lead to an improvement of long-term functional outcomes. Moreover regional analgesia procedures directly impair with quadriceps motor function interfering with rehabilitation.

The aim of this article is to analyze both anesthesia and surgical aspects causing quadriceps weakness after TKA and discuss their implication on functional outcomes.

Keywords: Total knee arthroplasty;Regional anesthesia;Quadriceps weakness

Background

Total knee arthroplasty (TKA) represents a major elective orthopedic surgery with the purpose to improves postoperative quality of life [1,2]. Several factors seems to affect long-term outcome after TKA; age, sex, alignment, type of the implant, and operative aspects such as surgical exposure techniques [3].

The physical-performance influencing the quality of life after TKA is range of motion (ROM), and quadriceps strength (QS). Both knee ROM and QS decrease after TKA. Six month is minimum timing required to return at preoperative levels for ROM [4], while QS two years after TKA is only 83% of the controlateral knee, and reduced a mean of 32,3% compared with controls [5].

With regards ROM, based-values to recover a good quality of life are 90° to navigate stairs, while to perform activities of daily living 110° of flexion is required [3].

Knee ROM is measured as active combined flexion/extension, but in most of cases it is measured passively with assistance. This latter case represents a limit in using knee ROM as an indicator of improvement for postoperative outcome. A great ROM is not sufficient if quadriceps weakness is continued after surgery. QS may impact activities of daily living by interfering with stability, standing endurance, navigating stairs, and ability of the patients to arise from a chair. For this reason a reduction in strength 1 year after TKA is a predictor of poor functional outcomes resulting in 50% slower walking and stairs-climbing speeds [6]. By contrast, patients with better quadriceps muscle strength showed more ability to complete all functional tests leading to a higher Knee Society Functional Score.

Quadriceps weakness after TKA may be due to a number of causes; postoperative analgesia due to regional anesthesia used, factors patient-related, surgical causes, as well as rehabilitation. The aim of this article is to analyze both anesthesia and surgical aspects causing quadriceps weakness after TKA and discuss their implication on functional outcomes.

Anesthesia Technique

Postoperative pain after TKA can be severe for days after surgery prolonging hospitalization, impairs rehabilitation and early mobilization [7]. Moreover acute postoperative pain is the first cause of persistent pain. It has been reported that up to 53% of patients complained persistent post surgical pain one year after TKA [8], representing the true limits to recover a good Knee Society Surgery Score.

Compared with traditional systemic opioids, regional anesthesia (RA) demonstrated superior analgesia with less adverse-effect[9,10]. Several studies also demonstrated that RA is associated with early mobilization, shortened length of hospital stay, reduced morbidity, and mortality [10-12]. In spite of these potential benefits, there is a lack of evidence that RA is associated with an improvement of functional outcomes after TKA [13]. A recent review of literature underlined several issue regarding RA and long-term functional outcomes: Few studies describe the effects of RA on functional outcomes and when reported they are underpowered or analyzed for insufficient duration postoperatively. Furthermore, clinical trials have usually reported VAS score or consumption of opiods as the primary outcome variable, and no studies of RA have assessed long-term function as the primary outcome variable[13].

Both lumbar plexus (LPB) and femoral nerve (FNB) blocks provide analgesia of anterior, lateral and medial portion on the knee representing a common regional analgesic choice after TKA. Continuous femoral nerve block provides several advantages in this setting compared with other regional anesthetic techniques: It is easy to perform with the same effectiveness than epidural and lumbar plexus analgesia but virtually with no adverse-effects[14]. The Major concern correlated with peripheral regional anesthetic techniques (either LPB or FNB) is motor block that impairs quadriceps function. Typically both LPB and FNB are associated with higher patient

satisfaction due to pain relief, early mobilization, and greater knee ROM during the first 48 postoperative hours [15]. Unfortunately this early advantages lead to some disadvantage when patient starts weight-bearing. Moreover, Marino et al. recently showed that quadriceps weakness during continuous femoral nerve block increases the risk of falls in patients receiving early rehabilitation after TKA [16]. Anyway, even in absence of regional block, one month postoperatively QS is expected to be reduced approximatively 60% [6]. Thus, after TKA QS may be reduced either from pain that limit muscular function, by (paradoxically) regional analgesic technique, or by a combination of both.

Motor block is a fundamental characteristic required to define a successful regional anesthesia but it is undesired in case of postoperative analgesia. Strategies are developing to prevent motor block during continuous peripheral nerve blocks. Taboada et al showed that using automatic intermittent bolus instead of continuous infusion, decreases the request of local anesthetic from the patient reducing the likelihood of incidental motor block [17]. New techniques such as stimulating catheters and ultrasound, leading to catheter nearest to the target nerve, allow a further reduction of local anesthetic volume (and dose), theoretically decreasing the incidence of motor block.

Recently, a new regional anesthetic technique has been introduced after knee orthopedic major surgery: adductor canal block (ACB). The adductor canal is an aponeurotic tunnel below the sartorious muscle in the middle third of the thigh containing sensory branches of the femoral nerve. Theoretically, the administration of local anesthetic at this level could avoid the undesired motor blockade while preserving analgesia. In a randomized, double-masked, placebo-controlledtrial on volunteers, continuous ACB resulted in a best analgesic profile compared with placebo in TKA patients, improving ambulation after 24 h [18]. By comparing with a "gold standard" femoral nerve block the ADB reduce quadriceps muscle strength only by 8%, versus 49% for the FNB [19]. Although these results are noteworthy future clinical trials should clarify the exact value of ADB as reliable analgesic technique after TKA, as well as how long adductor canal catheters should be maintained in order to optimize postoperative analgesia and rehabilitation.

With the aim to spare quadriceps motor function providing analgesia, periarticular infiltration (PAI) of a high volume of local anesthetic during TKA is gaining interest. The infiltration of local anesthetic in knee joint is a simple procedure performed by surgeon in soft tissue before component implantation, while catheter is leaved intrarticular. Previous study demonstrated a low impact of PAI on quadriceps function during TKA [20], although several PAI methods have been proposed with different results depending on type of the solutions used. A classical PAI solution included high volume of local anesthetic, opioids (theoretically with low adverse-effects than systemic administration), and epinephrine to prolong analgesia [21]. Debatable is the ads of steroid at the PAI solution to reduce inflammation. A recent double-blind comparison did not show any advantages in terms of pain, motion, and knee function when corticosteroids were added for knee infiltration [22]. Moreover the authors saw several complications in corticosteroids group with an important knee infection leading to death of the patient. Recently a phase-II clinical trial investigated several doses of liposomal bupivacaine for PAI use [23]. By comparing with bupivacaine HCL, 532 mg liposomal bupivacaine was associated with greater analgesia when the patients were at rest with duration up to 96h.

Unfortunately the overall small sample-size and the lack of procedures specific did not recommend PAI as first choice in case of TKA at the moment [24]. Furthermore when a rigorous method of comparison was applied PAI failed to achieve a satisfactory pain relief after TKA showing worse functional outcomes compared with FNB [26].

Surgical Exposure

Several surgical factors can affect either the short- or long-term recovery of quadriceps muscle after TKA. Recently many authors have highlighted the advantages of tissue sparing surgery, commonly referred as MIS (Mini Invasive Surgery) approach [27-29].

The common and worldwide spread medial parapatellar approach allows a complete exposure of the knee joint. Unfortunately, division of the quadriceps tendon and eversion of the patella can alterate the extensor mechanism balance, potentially leading to a patellofemoral maltreating or instability which are considered major complications after TKA [30]. Damage of the quadriceps tendon may affect the recovery of active extension in the first postoperative days, limiting early rehabilitation, as well as long-term functional outcomes [31]. The overstretching of quadriceps muscle fibers caused by eversion of the patella, and hyperflexed position essential for a conventional TKA, caused quadriceps muscle trauma as well as a muscle direct incision [32]. MIS approaches such as midvastus and subvastus approaches have been described to limit surgical exposure and have shown a good degree of reproducibility and efficacy in achieving a balanced and well-aligned TKA [33]. These techniques can slightly differ in some of surgical aspects, but they recognize important common features: sparing the quadriceps tendon, avoiding patellar eversion and tibio-femoral luxation. Compared to traditional surgical exposure techniques the speculated benefits of MIS approaches are an early better quadriceps motor function, postoperative pain relief, and a shorter length of hospital stay. The limits of MIS exposures could be the learning curve with technical related pitfalls, the use of these techniques in obese patients, as well as the lack of visualization, or limitations related to instrumentation and implant design [34].Although maintaining quadriceps function is mandatory in achieving an optimal short-term outcome, there is no evidence regarding the impact of MIS techniques in preventing postoperative long-term quadriceps weakness compared with standard medial parapatellar approach [35-38]. Moreover, MIS is referred to a heterogeneous group of surgical procedures. In midvastus approaches the incision is taken 2-3 cm into vastus medialis obliqus (VMO) [39]. This approach allows an easy and complete exposure of the knee joint but can disturb quadriceps function affecting control of patellar lateral translation during active extension. Subvastus arthrotomy is performed elevating the VMO muscle from its distal insertion and releasing it medially and proximally allowing patellar lateral translation. This approach limits invasivity on the quadriceps muscle and appears to better protect the muscle function. Moreover, it generally provides limited visibility of the lateral compartment when compared to standard approaches. In conclusion, the theoretical advantage of using a MIS approach for quadriceps function recovery seems to be strong only in the short-term with comparable results at mid- and long-term follow up. This trend has been recently confirmed in a recent clinical trial [40], which did not find any difference after 6 weeks between traditional and MIS arthroplasties regarding quadriceps strength.

Discussion

Impairments of quadriceps is a "democratic" complication after TKA involving either surgical and anesthetic techniques. In this article we discussed both anesthetic and orthopedic factors influencing quadriceps weakness aiming to find a common strategy to improve this important functional outcome. Decreasing postoperative pain maintaining QS is the main challenge for either anesthetists or surgeons during TKA. Actually, the more effectiveness postoperative analgesia techniques lead to impairments of quadriceps due to a motor block. On the other hand, a poor treatment of the acute postoperative pain resulting in a greater limitation in knee motion leading to quadriceps weakness and atrophy. This vicious circle is characteristic of this type of surgery.

The surgical and anesthetic techniques discussed in this article show most of benefits in early postoperative phase. Whereas MIS exposure may contribute to improve postoperative analgesia sparing quadriceps function compared with traditional TKA, RA has already demonstrated greater effectiveness in postoperative analgesia, but affecting quadriceps motor function. Adductor canal blockade could preserve quadriceps strength but it is a young technique and more clinical experimental evaluation is needed. Similar considerations should be done for PAI. The small sample, as well as the lack of procedures specific requires further rigorous clinical comparison in order to establish the exact role and which type of solutions is effective during TKA.

Unfortunately both MIS and RA do not seems to affects long-term functional outcomes. In this case, the absence of evidence does not equate to evidence of absence, and some consideration should be given.

A reduced intra-operative trauma on the quadriceps muscle and extensor following MIS exposure does not correspond to a little skin incision. In a recent randomized controlled trial, quadriceps strength improvement in the early postoperative period was not associated with improved functional performance[35], confirming also that the improvement in QS observed in early follow up after the MIS was not observable with longer follow up [40].

In spite of these controversial preliminary results, sparing quadriceps function while still providing postoperative analgesia are the primary goals for both the surgeon and anesthetist during TKA.

The main concerns are the lack of reproducibility due to other important factors influencing the outcome after TKA, such as patient pre-operative condition, gender, age, and rehabilitation, as well as the short duration of interventions to assess the outcome resulting in a small effect-size.

Having said this, common strategies between surgeons and anesthetists in future rigorous randomized clinical trials should be addressed to follow: (1) how long peripheral nerve catheters may be continued in order to optimize regional analgesia with rehabilitation, (2) assessing safety and reproducibility evaluating the real impact in outpatients. (3)To evaluate the real impact of MIS surgery on quadriceps function and its importance in achieving successful long-term clinical results, and (4) a more effective rehabilitation associated with a standardized surgical technique and optimal RA.

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