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ORIGINAL ARTICLE

Observational Study

Phenotypic profiling and characterization of stromal vascular fraction using two Novel adipose tissue processing systems

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Abstract

BACKGROUND

Adipose-derived stromal cells (ADSCs) are a mixed cell population, which includes, amongst others, mesenchymal stromal cells (MSCs). The first choice of cell isolation is subcutaneous adipose tissue as it is easily accessible, abundant and easily harvested by a less invasive procedure.

AIM

To determine the viability and phenotypic properties of the ADSCs that are treated by two procedures to induce stromal vascular fraction (SVF) by lipoaspirate, to verify that they can be used to ensure safe and efficient repair of articular cartilage defects.

METHODS

Lipoaspirate samples of adipose tissues were taken using various commercially

available systems of withdrawal. The cellular components of SFVs in untreated lipoaspirate samples were compared with similar cells obtained with the use of lipoaspirate samples treated with Lipogems® and Body-Jet® eco systems as a method of assessing cell composition and viability. The multicolour flow cytometry (FC) analysis was used to characterize the outputs.

RESULTS

Multicolour FC analysis revealed that SVF is composed of heterogeneous cell populations such as: (1) Adipose stem cells (CD45-CD90+CD73+CD34+ CD31- CD105-CD146-); (2) Endothelial progenitor cells (CD45-CD90+ CD73+CD34+ CD31+ CD105 LowCD146+); and (3) Pericytes (CD45-CD90+CD73+ CD34- CD31-CD105-CD146+), and other more or less characterized cells. The overall cell viability was similar across the groups. However, we observed a steady rise in the percentage of the endothelial cells and pericytes in the processed samples with Lipogems® and Body-Jet® eco systems in comparison to the untreated lipoaspirate samples.

CONCLUSION

Phenotypic characterization studies have suggested that MSC populations are found in a perivascular site with ADSCs shared with pericytes and endothelial cells. We have indications that the mechanical withdrawal steps can leave a large population heterogeneity of cells, retaining a more intricate tissue architecture (niche).

Key Words: Adipose tissue; Adipose-derived stromal cells; Mesenchymal stromal cells; Pericytes; Flow cytometry; Cartilage regeneration

Core Tip: Adipose-derived stromal cells (ADSCs) represent a heterogeneous population with mesenchymal stromal cells, pericytes, and endothelial progenitors. Subcutaneous adipose tissue provides a minimally invasive and abundant source for stromal vascular fraction isolation. A comparative analysis of untreated lipoaspirate *vs* Lipogems® and Body-Jet® eco systems revealed preserved viability and enhanced endothelial/pericyte proportions. Mechanical processing maintains cellular heterogeneity and niche architecture, thereby supporting the potential for safe and effective articular cartilage repair by ADSCs.

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INTRODUCTION

Current clinical treatments for articular cartilage regeneration today include different procedures, such as marrow stimulation techniques, osteochondral autograft transfers, autologous chondrocyte implantation (ACI), matrix-induced ACI and allografts[1]. Orthobiologics emerged as a promising treatment for regenerating musculoskeletal tissues that are well interconnected with the surrounding healthy bone, cartilage, muscles, tendons, and ligaments[2,3]. Orthobiologics include autologous peripheral blood-derived orthobiologics, stem cells of various tissue origins such as bone marrow, adipose tissue, amniotic fluid, placental tissues, dental pulp, hair follicle, periosteum, and menstrual blood, and exosomes of various tissue origins[4,5].

Adipose tissue has been considered a very promising source of adult stem cells in plastic surgery and regenerative medicine over the last ten years[6]. Subcutaneous adipose tissue has recently become the cell isolation of choice due to its accessibility *via* liposuction, relative abundance in most patients, possibility of transplantation in a minimally invasive procedure, and its safety and effectiveness in transplantation in an autologous or an allogeneic model[7,8]. This kind of tissue offers a rich supply of stromal vascular fraction (SVF) cells to be used immediately[9].

The SVF fraction consists of several types of cells, such as preadipocytes, mesenchymal stem cells (MSCs), endothelial progenitor cells (EPCs), fibroblasts, pericytes, and vascular smooth muscle cells. Several commercially available isolation systems can be used to isolate SVFs, to provide a reproducible and consistent cell mixture of heterogeneous cells[10-12]. After processing and administration, adipose-derived SVF cells have the potential to differentiate into many types of tissues, aid neovascularization, substitute damaged cells, and heal injured tissue[12]. Adipose tissue is now being used in the treatment of various morbidities, mainly when it is used as intact tissue (or as enzymatically processed SVF that can be used either fresh or after culture)[12,13].

To avoid enzymatic processing, non-enzymatic methods of cell separation with minimal manipulation utilize mechanical steps, such as centrifugation, pressure, filtration, and micro-fragmentation, to separate cells from adipose tissue [14-17]. Various closed systems have been established to culture and concentrate adipose tissue of a patient with minimal manipulation[14]. Specifically, the micro-fragmentation systems are crucial towards maintenance of the morphofunctional unit of the tissue[18]. This stromal niche contains a natural scaffold made up of extracellular matrix components which can support both structural organization and biological functionality. In its intact clusters and vascular stromal niches, the cellular counterpart maintains the differentiation and paracrine potential, which facilitates chondrogenic

regeneration in treated patients[19-21]. Pulsating water-jet-assisted systems are created to take advantage of the water-jet and defined vacuum and support adipose tissue harvesting without damaging the fat cells of the subcutaneous fat tissue and preserving them in a gentle state with high viability[22]. Furthermore, it has been possible to avoid any enzymatic intervention, which ultimately has allowed us to bring the acquired cellular products to clinical applications successfully.

However, the different processing systems used to acquire SVF may affect SVF cell composition and viability, potentially leading to varied clinical outcomes. Therefore, this report aims to characterize the cellular composition of the final adipose tissue samples obtained by micro-fragmentation or pulsating water-jet assisted filtration and concentration systems used for reconstructive surgery and compare these data to the ones obtained by the standard liposuction procedure, to evaluate the regenerative potential of these non-enzymatic adipose tissue transplants in comparison to that of enzymatically derived SVF. Since shortly after isolation of the cells from the tissue (within 24/48 hours), flow cytometric analysis can offer a better idea of the actual cellular composition allowing a comparison between different extraction methods. We decided to characterize by flow cytometry techniques the phenotypic profile of the cells isolated by using the Lipogems® system and the Body-Jet® eco system comparing them to the standard lipoaspirate procedure.

MATERIALS AND METHODS

Ethics approval

The study was approved by Institutional Ethics Committee, Sri Lalithambigai Medical College and Hospital.

Specimen collection

Tissue biopsies were collected from liposapirates of patients undergoing cartilage complex reconstructive surgeries or isolated hip or knee joint injections as osteoarthritis treatments, who provided study-specific informed consent for the research use of their tissue specimens.

Thirty patients (10 patients for each extraction method group: Standard lipoaspirate, Lipogems® system, and Body-Jet® eco system) were initially selected as the study group. Among these, due to the variable number of cells obtained in the samples and the study's aim to conduct analyses only on very fresh specimens, only three samples with enough cells to be freshly analyzed within the first 24-48 hours were finally selected from each group. Currently, we plan to continue the sample study by enrolling a higher number of participants, as it is not always possible to obtain enough cells for fresh analysis without *in vitro* amplification. It has been decided, therefore, among the ten samples retrieved for each technique, to present this paper describing the results obtained only on the three samples for each withdrawal method that contain enough cells (500000 cells/sample).

The three independent biopsies were harvested under local anaesthesia from the abdominal region with a 3 mm blunt cannula by standard sterile lipoaspiration technique, after infiltration of Klein's solution. 50-80 mL of lipoaspirate were subsequently processed using the Lipogems® kit (Lipogems International SpA, Milan, Italy) or the Body-Jet® eco kit (Human Med AG, Schwerin, Germany), following the manufacturer's instructions. Part of the samples remained unprocessed to serve as baseline samples for reference in cellular composition, biologics, and viability.

The Lipogems® system is a sterile, closed system that progressively and repeatedly reduces the size of adipose tissue clusters through filtration, emulsification, and removal of contaminating oil, blood, and debris, as well as washing. The Body-Jet® eco is a sterile, closed-loop system device that utilizes filtering, washing, and concentration of the lipoaspirate through the FillerCollector, which is connected to the Body-Jet® eco central apparatus. Exceeding adipose tissue Lipogems® or Body-Jet® eco processed samples, together with the relative unprocessed adipose tissue aliquot (10 mL each aliquot), were immediately transported to the laboratory and processed.

Adipose-derived stromal cells isolation

Lipoaspirate samples were processed as previously described by centrifugation according to the Coleman technique for fat harvesting. Briefly, each harvested fat sample was centrifuged at about 1500 rpm for 10 minutes to separate the material into three layers. The upper oil layer was removed from the sample with a large Gauge needle. Afterwards, enzymatic digestion was carried out by adding Collagenase Type II (Worthington Biochemical Corporation, Lakewood, NJ, United States) at a final concentration of 0.1% diluted in PBS. The sample was incubated at 37 °C for 45-50 minutes with gentle shaking. Enzymatic digestion was then halted by adding cell culture medium with L-glutamine containing 10% fetal bovine serum (FBS). Centrifugation of cells and fat was performed at a speed of 300 *g* for 5 minutes at room temperature. The pellets were resuspended in red cell lysis buffer (155 mmol/L NH_4Cl, 10 mmol/L $KHCO_3$, 0.1 mmol/L EDTA, pH 7.3) and left at 4 °C for 10 minutes. A 70 μm cell strainer (BD Biosciences) was used to filter the cell suspension, and it was subsequently centrifuged at 300 *g* for 5 minutes.

The cell pellet in the SVF cell was lastly seeded into a single T25 flask on DMEM supplemented with 20% FBS and antibiotics to select adherent cells. Within 24-48 hours, the cells attached to the plastic were analyzed using the flow cytometry technique.

Flow cytometry

The multiparametric panels used for flow cytometric analysis to evaluate the expression of stem cell-specific surface antigens were composed of the following conjugated antibodies: CD45-APC/Cy7, CD34-PE/Cy7, CD90-FITC, CD73-BV421, CD105-APC, CD31-PE, CD146-PE/CF594, CD271-PE, HLA-DR-PerCP/Cy5.5 (all from BD Bioscience, Milano, Italy), and Pref-1-PE (from Novus Biologicals, Milano, Italy).

Table 1 Flow cytometry analysis of adipose-derived stromal cell obtained by lipoaspirate, Lipogems® and Body-Jet® eco procedures, mean ± SD

Parameters	Lipoaspirate	Lipogems	Body-Jet eco
Live cells	63.66 ± 5.7	64.68 ± 8.7	65.10 ± 3.7
CD45-	70.23 ± 5.54	68.52 ± 7.41	67.91 ± 7.16
CD45-CD90+CD73+CD34+	95.46 ± 1.05	91.4 ± 4.1	92.18 ± 2.38
CD45-CD90+CD73+CD34+CD31+	6.07 ± 1.84	20.48 ± 5.48[a]	16.25 ± 1.94[b]
CD45-CD90+CD73+CD34+CD271+	44.60 ± 23.0	40.47 ± 11.67	34.76 ± 4.76
CD45-CD90+CD73+CD34+Pref-1+	1.35 ± 1.25	1.25 ± 0.45	1.12 ± 0.17
CD45-CD90+CD73+CD146+	4.55 ± 2.05	12.01 ± 2.21[c]	13.36 ± 2.96[b]
CD45-CD34-CD90+CD73+ CD146+	1.99 ± 1.45	6.96 ± 2.26[a]	7.23 ± 2.63[a]

[a]$P < 0.05$.
[b]$P < 0.01$.
[c]$P < 0.001$.

Sample labelling was carried out by detaching cells from the bottom of the flask by incubating for 10 minutes at 37 °C with Trypsin/EDTA. The enzyme was then inactivated with PBS containing 10% FBS and centrifuged at 250 *g* for 10 minutes at 4/8 °C. The cell pellets were resuspended in PBS and incubated with the monoclonal antibodies for 30 minutes at 4 °C. Samples were then washed by adding PBS and centrifuged at 250 *g* for 10 minutes at 4/8 °C. Finally, the samples were resuspended in a volume of PBS suitable for flow cytometer acquisition. Appropriate isotypes were used to set the negative controls.

Dead cell exclusion was performed using LIVE/DEAD™ fixable aqua dead cell stain (L34957, Thermo Fisher Scientific, NY, United States) according to the manufacturer's instructions. Briefly, cells in suspension were centrifuged at 250 *g* for 10 minutes at 4/8 °C. The cellular pellets were resuspended in PBS to 1 × 10^6 cells/mL. Reconstituted fluorescent reactive dye (1 µL) was added to the cell suspension and incubated at room temperature or on ice for 30 minutes, protected from light. The cells were washed twice with PBS and resuspended in a volume of PBS suitable for flow cytometry analysis.

Sample acquisitions were performed using a Gallios Flow cytometer (Beckman Coulter, Milan, Italy), equipped with three lasers (405 nm, 488 nm, 640 nm) and up to 10 fluorescent parameters. The analysis was then performed by using Kaluza Analysis Software v. 2.1 (Beckman Coulter).

Statistical analysis

In the figures, the single experiment and results are representative of the several experiments we performed on unprocessed liposapirates, Lipogems®, and Body-Jet® eco samples isolated from three different donors for each procedure. Quantitative data were reported as mean ± SD. The data were statistically analyzed using the student *t*-test. A *P* value of less than 0.05 was considered significant.

RESULTS

Flow cytometry analysis of the SVF cellular fraction was performed within the first 24-48 hours of seeding to minimize any phenotypic changes resulting from cell culture plastic adhesion. Multicolour FC analysis revealed that the SVF is composed of a heterogeneous cell population. We focused our analysis mostly on characterization and relative quantification of three cell types: (1) Adipose stem cells (CD45-CD90+CD73+CD34+ CD31- CD105-CD146-); (2) EPC (CD45-CD90+CD73+CD34+ CD31+ CD105 LowCD146+); and (3) Pericytes (D45-CD90+CD73+ CD34- CD31-CD105-CD146+) (Figure 1).

The analysis was conducted on live cells, which were excluded by staining them with LIVE/DEAD™ fixable aqua dead cell dye, as described in the materials and methods section. Dead cells were identified by plotting the forward scatter *vs* the aqua dead cell dye (not shown). The average number of live cells in all the samples is about 63%-65%. The mean values and relative standard deviations are shown in the first row of Table 1.

The CD271 (p75 neurotrophin receptor-p75NTR/LNGFR) was expressed in approximately 50% of the CD90+CD73+ CD34+ cells isolated from all extraction procedures (Figure 2A and Table 1). The expression levels of CD31 (Platelet endothelial cell adhesion molecule-PECAM-1) in Lipogems® isolated cells were significantly higher (3/4 times) than in cells isolated by standard procedure (lipoaspirate) (Figure 2B). They more than doubled in the Body-Jet® eco samples (Figure 2B and Table 1). All of them result in a positive for CD34, a possible indication of their stemness property. Notably, most CD31-positive cells also appear to express HLA-DR (Figure 2C). These cells are negative for CD45 and also co-express CD90, CD73, and CD34, and are negative for CD271, as indirectly established by comparing the expression of CD31 *vs* HLA-DR (Figure 2C) and the expression of CD271 *vs* HLA-DR (Figure 2D). Summarizing, most HLA-DR

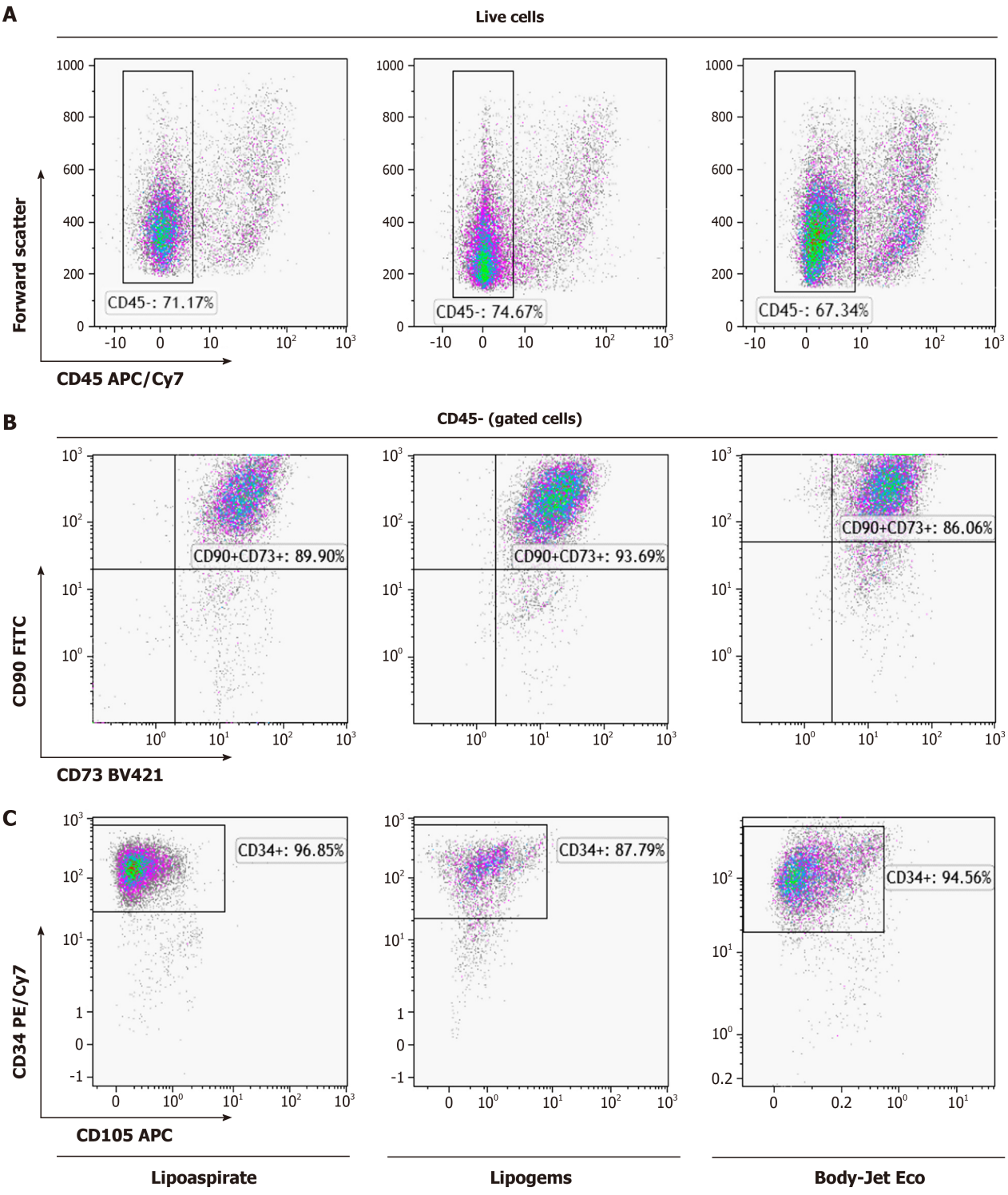


Figure 1 shows a comparison of surface marker analysis between lipoaspirate samples and samples isolated using Lipogems® and Body-Jet® eco. A: Approximately 68%-70% of live cells are negative for the CD45 expression; B: 90% of the CD45 negative cells are CD90+CD73+; C: CD34-positive at a high percentage and negative for CD105 (Endoglin) expression. Results are representative of at least three independent experiments for each isolation procedure.

positive cells are negative for CD271and positive for CD31 expression. This result is particularly noticeable in Lipogems® and Body-Jet® eco samples (Figure 2D), although it is unclear in lipoaspirate samples. Based on many scientific reports, the CD45-CD90+CD73+CD34+CD31+ population may be identified as EPC[23].

We also analyzed the expression of CD146 (a cell surface glycoprotein also known as MUC18) and the Pref-1 in CD45-CD90+CD73+ cells. Our comparison study confirms the presence of CD146+ cells in all techniques (Figure 3A). Notably, in Lipogems® and Body-Jet® eco, the percentage of CD146+CD34+ cells, identified as pericytes in the green boxed regions (Figure 3A), is approximately three times higher than in the lipoaspirate. These results recall what happens to CD31 in terms of quantitative increase comparing Lipogems® and Body-Jet® eco with lipoaspirate samples (Figure 2B and C).

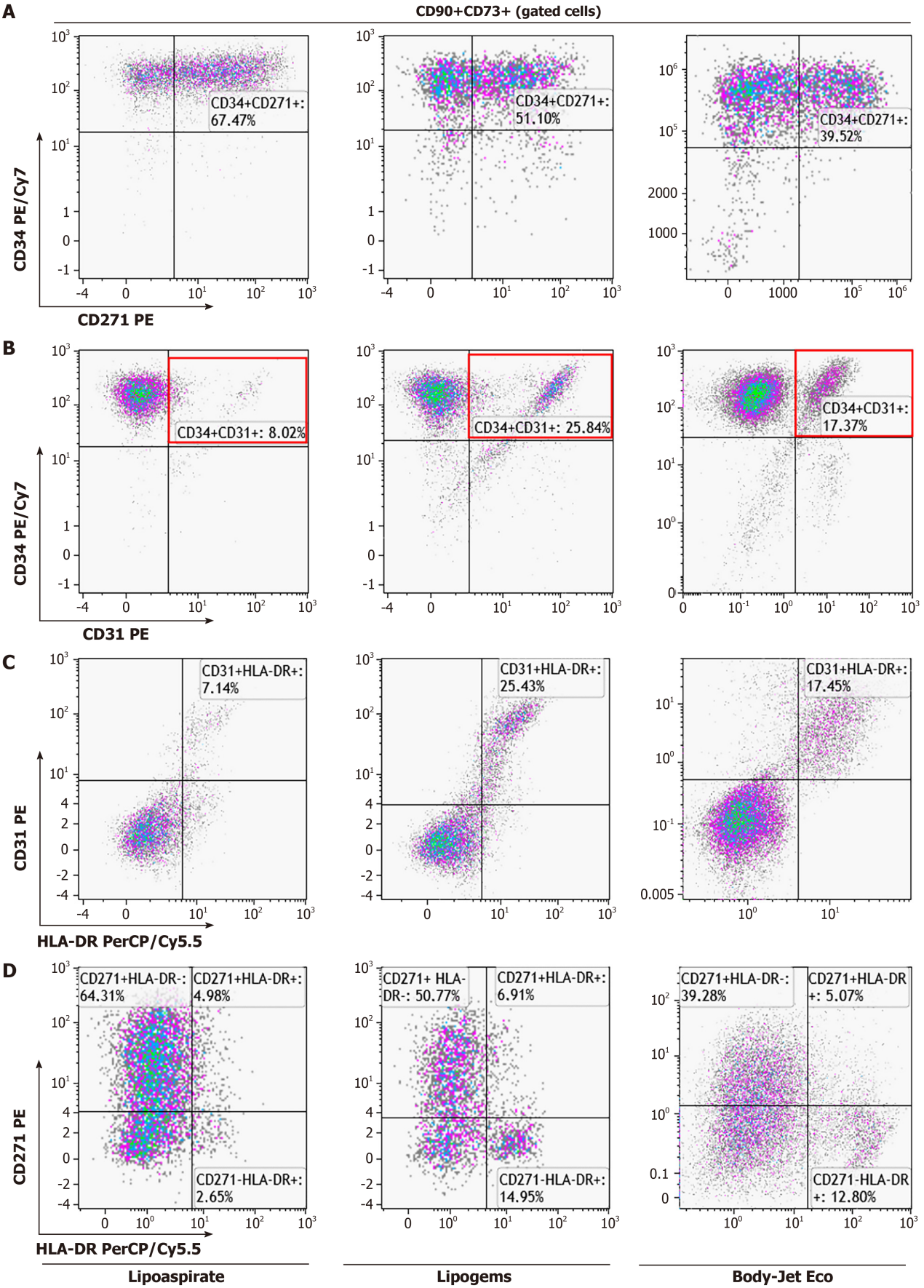


Figure 2 Flow cytometry analysis of adipose-derived stromal cells subpopulation. The analysis shown in this figure was carried out on CD90+CD73+ cells, which were negative for CD45 expression, as indicated on top of the density plots. A: The percentage of CD271- and CD34-positive cells in adipose-derived stromal cells isolated by Lipoaspirate, Lipogems®, and Body-Jet® eco procedures is reported; B: Cells positive for CD31 and CD34; C: A wide range of coexpression

with CD34 is observed. These cells are also HLA-DR-positive; D: Negative for CD271, as indirectly demonstrated. For greater clarity, red boxed regions highlight the endothelial progenitor cells. Results are representative of at least three independent experiments for each isolation procedure.

The percentages of Pref-1-positive cells in the three different adipose-derived stromal cell (ADSC) isolation procedures highlighted similar values, as shown in Figure 3B and Table 1 (approximately 1%). The Pref-1 subpopulation is predominantly CD34-positive (Figure 3B) and CD146-negative (Figure 3C). All the results are summarized in Table 1, showing the significant differences between the percentages of the populations analyzed using the three different procedures.

DISCUSSION

Lipoaspirate, when enzymatically digested, yields a heterogeneous population of many cell types (preadipocytes, fibroblasts, vascular smooth muscle cells, endothelial cells, resident monocytes/macrophages, lymphocytes, and ADSCs), known as SVF[24-28]. We aimed to investigate the viability and composition of freshly isolated cells from adipose tissue samples using Lipogems® and Body-Jet® eco procedures. The limitation of the present work is primarily due to the use of a single technique to compare the phenotypic analysis of cell populations extracted from adipose tissue using three different methods. The need to ensure both the therapeutic and experimental use of the extracted cells has significantly reduced the availability of materials that can be used for other functional evaluations, such as trilineage differentiation or production of cytokines, chemokines or growth factors.

However, the initial results of the phenotypic analysis of lipoaspirates, Lipogems®, and Body-Jet® eco samples indicate that approximately 90% of the CD45-negative cells are positive for CD34, a surface marker associated with stemness potential, whose expression tends to decrease during *in vitro* culture[29,30].

Comparing the lipoaspirates with Lipogems® and Body-Jet® eco treated adipose tissues, we found an increased number of EPCs and pericytes in Lipogems® and in Body-Jet® eco samples. As shown in Figure 2B, the CD34+/CD31+ EPC population is more than tripled in the Lipogems® sample and more than doubled in the Body-Jet® eco sample, indicating an enrichment of this subpopulation due to the manipulation procedure. In addition, these cells were CD105 (Endoglin) negative, although the MSCs "consensus" by Dominici *et al*[31] typically considers MSCs to be CD34-negative and CD105-positive. This discrepancy, observed and described by various authors, is attributed to the different times at which the analysis is conducted[32]. Some expression markers observed in freshly isolated MSCs are heavily modulated by subsequent *in vitro* culture conditions and by adhesion to the support, as often described in the literature[33]. It has been reported that the subpopulation of CD105-negative MSCs exhibits a stronger immunomodulatory capacity compared to CD105-positive MSCs, which may be related to the autocrine production of transforming growth factor-beta 1. The authors suggest that these types of cells could represent a promising tool in regenerative medicine[34-36].

In the present study, we demonstrate that most CD31-positive cells also express HLA-DR (Figure 2C), a component of the MHC class II HLA molecules. Class II molecules are expressed only on B lymphocytes, antigen-presenting cells (including monocytes, macrophages, and dendritic cells), and activated T lymphocytes[37] or renal microvascular endothelial cells[38]. Considering their negativity for CD45, we exclude any possible hematopoietic nature for the observed population. The expression of HLA-DR on freshly isolated MSCs has been reported. It is triggered *in vitro* by interferon-γ and other pro-inflammatory stimuli[39-41], including tumour necrosis factor-α, interleukin-1, various chemokines, leukotrienes, and free radicals[41,42]. Under similar inflammatory conditions, literature data show that the expression of MHC class II molecules by human microvascular endothelial cells allows them to orient the CD4+T cell response towards either a Th17 pro-inflammatory response or a regulatory T cell response[43]. Considering the co-expression of both surface markers CD31, CD34 and HLA-DR, in our opinion, we face an EPC population that atypically expresses HLA-DR.

We hypothesize that the acute tissue damage resulting from the liposuction procedure is likely responsible for the release of pro-inflammatory components, leading to the anomalous expression of HLA-DR on the isolated SVF cells. The consistently higher percentage of HLA-DR-positive cells in the processed samples could be due to both extraction methods tending to a significant concentration of EPCs. Nevertheless, its role and actual presence in SVF cells are still controversial and require further in-depth analysis[44].

Regarding the expression of CD271, as mentioned earlier, it has been detected in approximately 50% of the CD45-CD90+CD73+CD34+ cells isolated from all extraction procedures (Figure 2A and Table 1). This marker is proposed as a versatile MSCs marker with multi-potential differentiation capacity[45,46]. CD271+ MSCs exhibited higher expansion potential and higher expression of chondrogenic genes compared to the control group[47]. Furthermore, CD271-selected MSCs from adipose tissue improve cartilage repair by restoration of mature perivascular tissues as well as articular cartilage[48].

The same observation is applicable for the pericytes (CD45-CD90+CD73+CD146+CD34-) subpopulation, which, as shown in Figure 3B, is three times more concentrated in Lipogems® and Body-Jet® eco samples than in untreated lipoaspirate tissue. Pericytes possess stem cell-like properties, and it has been hypothesized that they represent the *in vivo* counterparts, or perhaps precursors, of MSCs[49-51]. This type of perivascular cell is closely associated with endothelial cells and plays essential roles in maintaining blood vessels and promoting angiogenesis[52]. Lastly, the early adipose precursor cells found in the processed SVF samples should be detected. We determined the number of Pref-1-expressing cells. Pref-1 (also called Dlk1/FA1) is an anti-adipocyte differentiation inhibitor that is produced in the plasma. Six EGF-repeats of a membrane protein with six EGF-repeats in the extracellular domain. Pref-1 is expressed in preadipocytes, but

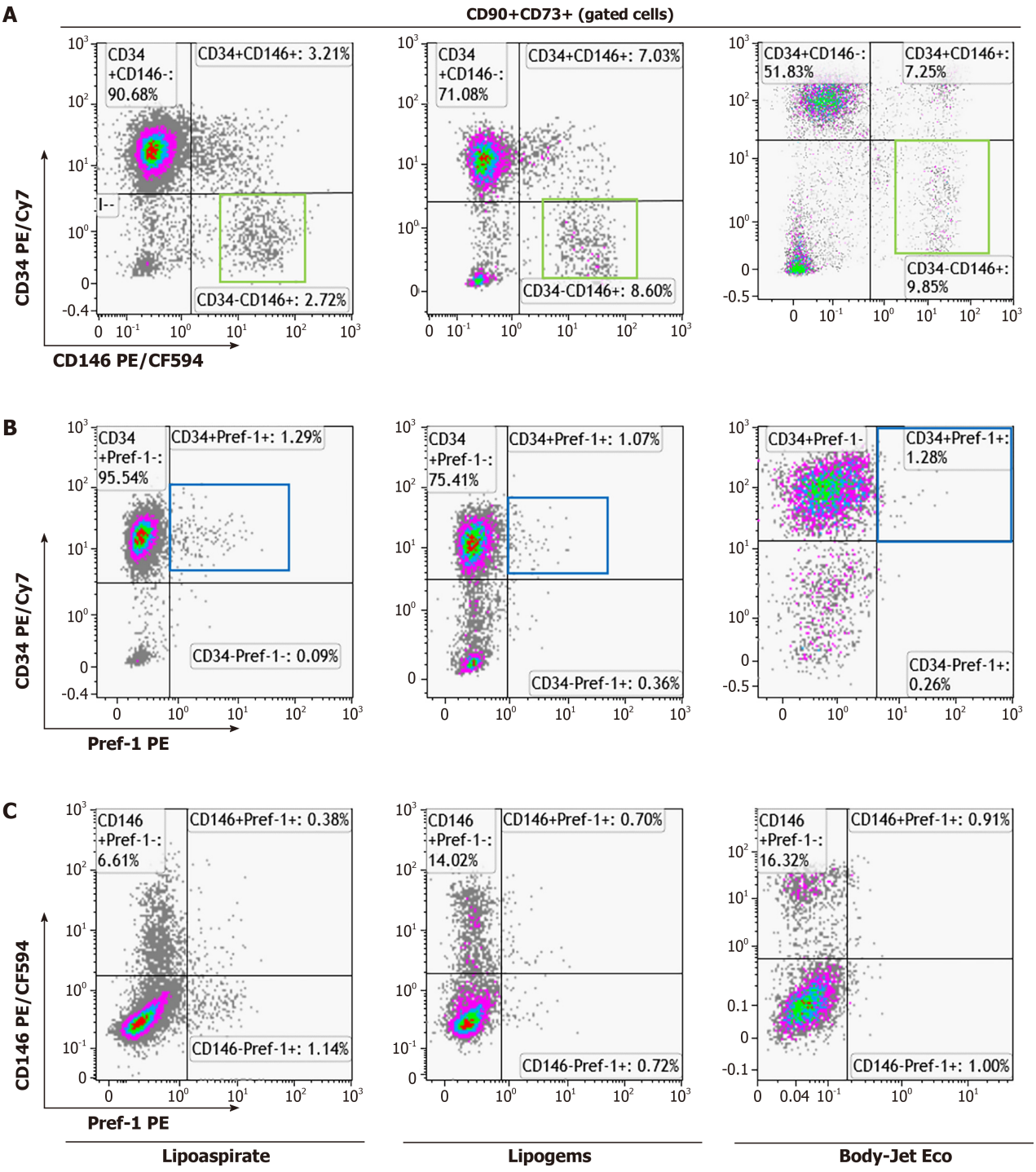


Figure 3 Flow cytometry analysis of pericytes and preadipocytes. A and B: Analysis of CD34, CD146 and Pref-1 was performed on the CD90+ CD73+CD45- cells, as indicated on top of the density plots. Density plots of CD34 *vs* CD146 and CD34 *vs* Pref-1, respectively. Pericytes subpopulation (CD90+CD73+CD45- CD34-CD146+) is highlighted by green boxed regions, while preadipocyte subpopulation (CD90+CD73+CD45- CD34+ Pref-1+), characterized by Pref-1 and CD34 co-expression, is highlighted by blue boxed areas; C: Density plots of CD146 *vs* Pref-1, indicating their partial co-expression. Results are representative of at least three independent experiments for each isolation procedure.

not in the mature fat cells[53]. The occurrence of a low percentage of Pref-1 + cells might indicate, as we think, the remaining pool of very early adipocyte progenitors. Mitterberger *et al*[54] found that the majority of hASCs express Pref-1 and that the expression of Pref-1 decreases during adipogenic differentiation[54]. Based on the literature information about murine. Pref-1-marked adipose progenitors, these, are not of endothelial or pericyte origin, but rather are mesenchymal[55]. As described, the Pref-1 detection is rapidly lost in cultured cells; however, we still assume it could be relevant for their regenerative potential *in vivo*.

Considering that cartilage has a limited self-repair capacity, current surgical repair techniques for articular cartilage pathologies are insufficient to halt the development and progression of osteoarthritis. This has accelerated the development of alternative tissue engineering strategies. Intra-articular tissue injections (such as fat grafts) obtained from

lipoaspirate by mechanical means without the use of enzymatic digestion, but only through mechanical processing, allowing the maintenance of the original relevant characteristics of the tissue relating to its utility for reconstruction, repair or replacement. The present results suggest that adipose tissue resident regenerative cells perform these functions much more efficiently when maintained in the intact perivascular environment, like provided by a mechanical fragmentation system. The enrichment in pericytes and EPC in the processed fat samples, together with a tissue volume reduction, make the described techniques more suitable for intra-articular therapies in terms of cartilage regeneration and local neovascularization, providing support and potential healing and improving joint functionality and pain relief.

CONCLUSION

SVF derived from adipose tissue demonstrates a heterogeneous mix of mesenchymal stromal cells, endothelial progenitors, and pericytes. Mechanical processing systems, such as Lipogems® and Body-Jet® eco, enrich these regenerative populations while preserving perivascular niches and overall cell viability. The enhanced presence of pericytes and endothelial cells supports cartilage repair and neovascularization, underscoring non-enzymatic SVF isolation as a clinically promising approach for orthobiologic therapies aimed at joint regeneration and functional recovery.

REFERENCES

1 **Cong B**, Sun T, Zhao Y, Chen M. Current and Novel Therapeutics for Articular Cartilage Repair and Regeneration. *Ther Clin Risk Manag* 2023; **19**: 485-502 [*RCA*] [PMID: 37360195 DOI: 10.2147/TCRM.S410277] [FullText] [Full Text(PDF)]

2 **Costa FR**, Pires L, Martins RA, Santos M, Santos GS, Lana JV, Costa BR, Santos N, de Macedo AP, Kruel A, Lana JF. Orthobiologics Revisited: A Concise Perspective on Regenerative Orthopedics. *Curr Issues Mol Biol* 2025; **47**: 247 [*RCA*] [PMID: 40699646 DOI: 10.3390/cimb47040247] [FullText] [Full Text(PDF)]

3 **Bacakova L**, Zarubova J, Travnickova M, Musilkova J, Pajorova J, Slepicka P, Kasalkova NS, Svorcik V, Kolska Z, Motarjemi H, Molitor M. Stem cells: their source, potency and use in regenerative therapies with focus on adipose-derived stem cells - a review. *Biotechnol Adv* 2018; **36**: 1111-1126 [*RCA*] [PMID: 29563048 DOI: 10.1016/j.biotechadv.2018.03.011] [FullText]

4 **Muthu S**, Jeyaraman M, Jain R, Gulati A, Jeyaraman N, Prajwal GS, Mishra PC. Accentuating the sources of mesenchymal stem cells as cellular therapy for osteoarthritis knees-a panoramic review. *Stem Cell Investig* 2021; **8**: 13 [*RCA*] [PMID: 34386542 DOI: 10.21037/sci-2020-055] [FullText]

5 **Muthu S**, Bapat A, Jain R, Jeyaraman N, Jeyaraman M. Exosomal therapy-a new frontier in regenerative medicine. *Stem Cell Investig* 2021; **8**: 7 [*RCA*] [PMID: 33969112 DOI: 10.21037/sci-2020-037] [FullText]

6 **Al-Ghadban S**, Artiles M, Bunnell BA. Adipose Stem Cells in Regenerative Medicine: Looking Forward. *Front Bioeng Biotechnol* 2021; **9**: 837464 [*RCA*] [PMID: 35096804 DOI: 10.3389/fbioe.2021.837464] [FullText] [Full Text(PDF)]

7 **Si Z**, Wang X, Sun C, Kang Y, Xu J, Wang X, Hui Y. Adipose-derived stem cells: Sources, potency, and implications for regenerative therapies. *Biomed Pharmacother* 2019; **114**: 108765 [*RCA*] [PMID: 30921703 DOI: 10.1016/j.biopha.2019.108765] [FullText]

8 **Mazini L**, Rochette L, Amine M, Malka G. Regenerative Capacity of Adipose Derived Stem Cells (ADSCs), Comparison with Mesenchymal Stem Cells (MSCs). *Int J Mol Sci* 2019; **20**: 2523 [*RCA*] [PMID: 31121953 DOI: 10.3390/ijms20102523] [FullText] [Full Text(PDF)]

9 **Ramakrishnan VM**, Boyd NL. The Adipose Stromal Vascular Fraction as a Complex Cellular Source for Tissue Engineering Applications. *Tissue Eng Part B Rev* 2018; **24**: 289-299 [*RCA*] [PMID: 28316259 DOI: 10.1089/ten.TEB.2017.0061] [FullText]

10 **Liu ZH**, Xie QQ, Huang JL. Stromal vascular fraction: Mechanisms and application in reproductive disorders. *World J Stem Cells* 2025; **17**: 101097 [*RCA*] [PMID: 39866896 DOI: 10.4252/wjsc.v17.i1.101097] [FullText] [Full Text(PDF)]

11 **Cremona M**, Gallazzi M, Rusconi G, Mariotta L, Gola M, Soldati G. State of the Art in the Standardization of Stromal Vascular Fraction Processing. *Biomolecules* 2025; **15**: 199 [*RCA*] [PMID: 40001502 DOI: 10.3390/biom15020199] [FullText] [Full Text(PDF)]

12 **Jeyaraman N**, Shrivastava S, Ravi VR, Nallakumarasamy A, Pundkar A, Jeyaraman M. Understanding and controlling the variables for stromal vascular fraction therapy. *World J Stem Cells* 2024; **16**: 784-798 [*RCA*] [PMID: 39219728 DOI: 10.4252/wjsc.v16.i8.784] [FullText] [Full Text(PDF)]

13 **Sharma S**, Muthu S, Jeyaraman M, Ranjan R, Jha SK. Translational products of adipose tissue-derived mesenchymal stem cells: Bench to bedside applications. *World J Stem Cells* 2021; **13**: 1360-1381 [*RCA*] [PMID: 34786149 DOI: 10.4252/wjsc.v13.i10.1360] [FullText] [Full Text(PDF)]

14 **Mundluru VK**, Naidu MJ, Mundluru RT, Jeyaraman N, Muthu S, Ramasubramanian S, Jeyaraman M. Non-enzymatic methods for isolation of stromal vascular fraction and adipose-derived stem cells: A systematic review. *World J Methodol* 2024; **14**: 94562 [PMID: 38983657 DOI: 10.5662/wjm.v14.i2.94562] [FullText]

15 **Oberbauer E**, Steffenhagen C, Wurzer C, Gabriel C, Redl H, Wolbank S. Enzymatic and non-enzymatic isolation systems for adipose tissue-derived cells: current state of the art. *Cell Regen* 2015; **4**: 7 [*RCA*] [PMID: 26435835 DOI: 10.1186/s13619-015-0020-0] [FullText] [Full Text(PDF)]

16 **Busato A**, De Francesco F, Biswas R, Mannucci S, Conti G, Fracasso G, Conti A, Riccio V, Riccio M, Sbarbati A. Simple and Rapid Non-Enzymatic Procedure Allows the Isolation of Structurally Preserved Connective Tissue Micro-Fragments Enriched with SVF. *Cells* 2020; **10**: 36 [*RCA*] [PMID: 33383682 DOI: 10.3390/cells10010036] [FullText] [Full Text(PDF)]

17 **Yaylacı S**, Kaçaroğlu D, Hürkal Ö, Ulaşlı AM. An enzyme-free technique enables the isolation of a large number of adipose-derived stem cells at the bedside. *Sci Rep* 2023; **13**: 8005 [*RCA*] [PMID: 37198228 DOI: 10.1038/s41598-023-34915-0] [FullText]

18 **Weinzierl A**, Harder Y, Schmauss D, Menger MD, Laschke MW. Microvascular Fragments Protect Ischemic Musculocutaneous Flap Tissue from Necrosis by Improving Nutritive Tissue Perfusion and Suppressing Apoptosis. *Biomedicines* 2023; **11**: 1454 [*RCA*] [PMID: 37239125 DOI: 10.3390/biomedicines11051454] [FullText]

19 **Wu J**, He Y, Qian T, Liu Z, Wu Y, Li Y, Jiang H, Ye J, Lv J, Ma B, Luo E, You J, Wang D, Bai Y, Zhang J, Zuo L, Peng J. Stromal vascular

fraction self-assembles vascularized osteogenic organoids with immunomodulatory functions. *Bioact Mater* 2026; **57**: 323-343 [*RCA*] [PMID: 41323199 DOI: 10.1016/j.bioactmat.2025.10.030] [FullText] [Full Text(PDF)]

20 **Molnar V**, Pavelić E, Vrdoljak K, Čemerin M, Klarić E, Matišić V, Bjelica R, Brlek P, Kovačić I, Tremolada C, Primorac D. Mesenchymal Stem Cell Mechanisms of Action and Clinical Effects in Osteoarthritis: A Narrative Review. *Genes (Basel)* 2022; **13**: 949 [*RCA*] [PMID: 35741711 DOI: 10.3390/genes13060949] [FullText] [Full Text(PDF)]

21 **Yuan C**, Song W, Jiang X, Wang Y, Li C, Yu W, He Y. Adipose-derived stem cell-based optimization strategies for musculoskeletal regeneration: recent advances and perspectives. *Stem Cell Res Ther* 2024; **15**: 91 [*RCA*] [PMID: 38539224 DOI: 10.1186/s13287-024-03703-6] [FullText]

22 **Yin S**, Luan J, Fu S, Wang Q, Zhuang Q. Does water-jet force make a difference in fat grafting? In vitro and in vivo evidence of improved lipoaspirate viability and fat graft survival. *Plast Reconstr Surg* 2015; **135**: 127-138 [*RCA*] [PMID: 25285679 DOI: 10.1097/PRS.0000000000000780] [FullText]

23 **Lion J**, Taflin C, Cross AR, Robledo-Sarmiento M, Mariotto E, Savenay A, Carmagnat M, Suberbielle C, Charron D, Haziot A, Glotz D, Mooney N. HLA Class II Antibody Activation of Endothelial Cells Promotes Th17 and Disrupts Regulatory T Lymphocyte Expansion. *Am J Transplant* 2016; **16**: 1408-1420 [*RCA*] [PMID: 26614587 DOI: 10.1111/ajt.13644] [FullText]

24 **Palumbo P**, Lombardi F, Siragusa G, Cifone MG, Cinque B, Giuliani M. Methods of Isolation, Characterization and Expansion of Human Adipose-Derived Stem Cells (ASCs): An Overview. *Int J Mol Sci* 2018; **19**: 1897 [*RCA*] [PMID: 29958391 DOI: 10.3390/ijms19071897] [Full Text] [Full Text(PDF)]

25 **Polancec D**, Zenic L, Hudetz D, Boric I, Jelec Z, Rod E, Vrdoljak T, Skelin A, Plecko M, Turkalj M, Nogalo B, Primorac D. Immunophenotyping of a Stromal Vascular Fraction from Microfragmented Lipoaspirate Used in Osteoarthritis Cartilage Treatment and Its Lipoaspirate Counterpart. *Genes (Basel)* 2019; **10**: 474 [*RCA*] [PMID: 31234442 DOI: 10.3390/genes10060474] [FullText] [Full Text(PDF)]

26 **Ong WK**, Chakraborty S, Sugii S. Adipose Tissue: Understanding the Heterogeneity of Stem Cells for Regenerative Medicine. *Biomolecules* 2021; **11**: 918 [*RCA*] [PMID: 34206204 DOI: 10.3390/biom11070918] [FullText] [Full Text(PDF)]

27 **Zuk PA**, Zhu M, Ashjian P, De Ugarte DA, Huang JI, Mizuno H, Alfonso ZC, Fraser JK, Benhaim P, Hedrick MH. Human adipose tissue is a source of multipotent stem cells. *Mol Biol Cell* 2002; **13**: 4279-4295 [*RCA*] [PMID: 12475952 DOI: 10.1091/mbc.e02-02-0105] [FullText]

28 **Di Taranto G**, Cicione C, Visconti G, Isgrò MA, Barba M, Di Stasio E, Stigliano E, Bernardini C, Michetti F, Salgarello M, Lattanzi W. Qualitative and quantitative differences of adipose-derived stromal cells from superficial and deep subcutaneous lipoaspirates: a matter of fat. *Cytotherapy* 2015; **17**: 1076-1089 [*RCA*] [PMID: 26002819 DOI: 10.1016/j.jcyt.2015.04.004] [FullText]

29 **Mitchell JB**, McIntosh K, Zvonic S, Garrett S, Floyd ZE, Kloster A, Di Halvorsen Y, Storms RW, Goh B, Kilroy G, Wu X, Gimble JM. Immunophenotype of human adipose-derived cells: temporal changes in stromal-associated and stem cell-associated markers. *Stem Cells* 2006; **24**: 376-385 [*RCA*] [PMID: 16322640 DOI: 10.1634/stemcells.2005-0234] [FullText]

30 **Maumus M**, Peyrafitte JA, D'Angelo R, Fournier-Wirth C, Bouloumié A, Casteilla L, Sengenès C, Bourin P. Native human adipose stromal cells: localization, morphology and phenotype. *Int J Obes (Lond)* 2011; **35**: 1141-1153 [*RCA*] [PMID: 21266947 DOI: 10.1038/ijo.2010.269] [FullText] [Full Text(PDF)]

31 **Dominici M**, Le Blanc K, Mueller I, Slaper-Cortenbach I, Marini F, Krause D, Deans R, Keating A, Prockop Dj, Horwitz E. Minimal criteria for defining multipotent mesenchymal stromal cells. The International Society for Cellular Therapy position statement. *Cytotherapy* 2006; **8**: 315-317 [*RCA*] [PMID: 16923606 DOI: 10.1080/14653240600855905] [FullText]

32 **Planat-Benard V**, Silvestre JS, Cousin B, André M, Nibbelink M, Tamarat R, Clergue M, Manneville C, Saillan-Barreau C, Duriez M, Tedgui A, Levy B, Pénicaud L, Casteilla L. Plasticity of human adipose lineage cells toward endothelial cells: physiological and therapeutic perspectives. *Circulation* 2004; **109**: 656-663 [*RCA*] [PMID: 14734516 DOI: 10.1161/01.CIR.0000114522.38265.61] [FullText]

33 **Bourin P**, Bunnell BA, Casteilla L, Dominici M, Katz AJ, March KL, Redl H, Rubin JP, Yoshimura K, Gimble JM. Stromal cells from the adipose tissue-derived stromal vascular fraction and culture expanded adipose tissue-derived stromal/stem cells: a joint statement of the International Federation for Adipose Therapeutics and Science (IFATS) and the International Society for Cellular Therapy (ISCT). *Cytotherapy* 2013; **15**: 641-648 [*RCA*] [PMID: 23570660 DOI: 10.1016/j.jcyt.2013.02.006] [FullText] [Full Text(PDF)]

34 **Desando G**, Bartolotti I, Cattini L, Tschon M, Martini L, Fini M, Schiavinato A, Soranzo C, Grigolo B. Prospects on the Potential In Vitro Regenerative Features of Mechanically Treated-Adipose Tissue for Osteoarthritis Care. *Stem Cell Rev Rep* 2021; **17**: 1362-1373 [*RCA*] [PMID: 33469783 DOI: 10.1007/s12015-020-10099-2] [FullText] [Full Text(PDF)]

35 **Pham LH**, Vu NB, Van Pham P. The subpopulation of CD105 negative mesenchymal stem cells show strong immunomodulation capacity compared to CD105 positive mesenchymal stem cells. *Biomed Res Ther* 2019; **6**: 3131-3140 [*RCA*] [DOI: 10.15419/bmrat.v6i4.538] [FullText]

36 **Van Dongen JA**, Gostelie OFE, Vonk LA, De Bruijn JJ, Van Der Lei B, Harmsen MC, Stevens HP. Fractionation of Adipose Tissue Procedure With a Disposable One-Hole Fractionator. *Aesthet Surg J* 2020; **40**: NP194-NP201 [*RCA*] [PMID: 31402379 DOI: 10.1093/asj/sjz223] [FullText]

37 **Choo SY**. The HLA system: genetics, immunology, clinical testing, and clinical implications. *Yonsei Med J* 2007; **48**: 11-23 [*RCA*] [PMID: 17326240 DOI: 10.3349/ymj.2007.48.1.11] [FullText] [Full Text(PDF)]

38 **Muczynski KA**, Ekle DM, Coder DM, Anderson SK. Normal human kidney HLA-DR-expressing renal microvascular endothelial cells: characterization, isolation, and regulation of MHC class II expression. *J Am Soc Nephrol* 2003; **14**: 1336-1348 [*RCA*] [PMID: 12707403 DOI: 10.1097/01.asn.0000061778.08085.9f] [FullText]

39 **Polchert D**, Sobinsky J, Douglas G, Kidd M, Moadsiri A, Reina E, Genrich K, Mehrotra S, Setty S, Smith B, Bartholomew A. IFN-gamma activation of mesenchymal stem cells for treatment and prevention of graft versus host disease. *Eur J Immunol* 2008; **38**: 1745-1755 [*RCA*] [PMID: 18493986 DOI: 10.1002/eji.200738129] [FullText] [Full Text(PDF)]

40 **Le Blanc K**, Tammik C, Rosendahl K, Zetterberg E, Ringdén O. HLA expression and immunologic properties of differentiated and undifferentiated mesenchymal stem cells. *Exp Hematol* 2003; **31**: 890-896 [*RCA*] [PMID: 14550804 DOI: 10.1016/s0301-472x(03)00110-3] [FullText]

41 **Zachar L**, Bačenková D, Rosocha J. Activation, homing, and role of the mesenchymal stem cells in the inflammatory environment. *J Inflamm Res* 2016; **9**: 231-240 [*RCA*] [PMID: 28008279 DOI: 10.2147/JIR.S121994] [FullText]

42 **Krysko DV**, Denecker G, Festjens N, Gabriels S, Parthoens E, D'Herde K, Vandenabeele P. Macrophages use different internalization mechanisms to clear apoptotic and necrotic cells. *Cell Death Differ* 2006; **13**: 2011-2022 [*RCA*] [PMID: 16628234 DOI: 10.1038/sj.cdd.4401900] [FullText]

43 **Taflin C**, Favier B, Baudhuin J, Savenay A, Hemon P, Bensussan A, Charron D, Glotz D, Mooney N. Human endothelial cells generate Th17

and regulatory T cells under inflammatory conditions. *Proc Natl Acad Sci U S A* 2011; **108**: 2891-2896 [*RCA*] [PMID: 21282653 DOI: 10.1073/pnas.1011811108] [FullText]

44 **Grau-Vorster M**, Laitinen A, Nystedt J, Vives J. HLA-DR expression in clinical-grade bone marrow-derived multipotent mesenchymal stromal cells: a two-site study. *Stem Cell Res Ther* 2019; **10**: 164 [*RCA*] [PMID: 31196185 DOI: 10.1186/s13287-019-1279-9] [FullText] [Full Text(PDF)]

45 **Álvarez-Viejo M**, Menéndez-Menéndez Y, Otero-Hernández J. CD271 as a marker to identify mesenchymal stem cells from diverse sources before culture. *World J Stem Cells* 2015; **7**: 470-476 [*RCA*] [PMID: 25815130 DOI: 10.4252/wjsc.v7.i2.470] [FullText] [Full Text(PDF)]

46 **Kohli N**, Al-Delfi IRT, Snow M, Sakamoto T, Miyazaki T, Nakajima H, Uchida K, Johnson WEB. CD271-selected mesenchymal stem cells from adipose tissue enhance cartilage repair and are less angiogenic than plastic adherent mesenchymal stem cells. *Sci Rep* 2019; **9**: 3194 [*RCA*] [PMID: 30816233 DOI: 10.1038/s41598-019-39715-z] [FullText] [Full Text(PDF)]

47 **Mifune Y**, Matsumoto T, Murasawa S, Kawamoto A, Kuroda R, Shoji T, Kuroda T, Fukui T, Kawakami Y, Kurosaka M, Asahara T. Therapeutic Superiority for Cartilage Repair by CD271-Positive Marrow Stromal Cell Transplantation. *Cell Transplant* 2013; **22**: 1201-1211 [*RCA*] [DOI: 10.3727/096368912X657378] [FullText]

48 **Fu X**, Chen Y, Xie FN, Dong P, Liu WB, Cao Y, Zhang WJ, Xiao R. Comparison of immunological characteristics of mesenchymal stem cells derived from human embryonic stem cells and bone marrow. *Tissue Eng Part A* 2015; **21**: 616-626 [*RCA*] [PMID: 25256849 DOI: 10.1089/ten.TEA.2013.0651] [FullText] [Full Text(PDF)]

49 **Crisan M**, Yap S, Casteilla L, Chen CW, Corselli M, Park TS, Andriolo G, Sun B, Zheng B, Zhang L, Norotte C, Teng PN, Traas J, Schugar R, Deasy BM, Badylak S, Buhring HJ, Giacobino JP, Lazzari L, Huard J, Péault B. A perivascular origin for mesenchymal stem cells in multiple human organs. *Cell Stem Cell* 2008; **3**: 301-313 [*RCA*] [PMID: 18786417 DOI: 10.1016/j.stem.2008.07.003] [FullText]

50 **Feng J**, Mantesso A, Sharpe PT. Perivascular cells as mesenchymal stem cells. *Expert Opin Biol Ther* 2010; **10**: 1441-1451 [*RCA*] [PMID: 20836622 DOI: 10.1517/14712598.2010.517191] [FullText]

51 **Díaz-Flores L**, Gutiérrez R, Madrid JF, Varela H, Valladares F, Acosta E, Martín-Vasallo P, Díaz-Flores L Jr. Pericytes. Morphofunction, interactions and pathology in a quiescent and activated mesenchymal cell niche. *Histol Histopathol* 2009; **24**: 909-969 [*RCA*] [PMID: 19475537 DOI: 10.14670/HH-24.909] [FullText]

52 **Lin CS**, Ning H, Lin G, Lue TF. Is CD34 truly a negative marker for mesenchymal stromal cells? *Cytotherapy* 2012; **14**: 1159-1163 [*RCA*] [PMID: 23066784 DOI: 10.3109/14653249.2012.729817] [FullText] [Full Text(PDF)]

53 **Sul HS**, Smas C, Mei B, Zhou L. Function of pref-1 as an inhibitor of adipocyte differentiation. *Int J Obes Relat Metab Disord* 2000; **24** Suppl 4: S15-S19 [*RCA*] [PMID: 11126233 DOI: 10.1038/sj.ijo.0801494] [FullText]

54 **Mitterberger MC**, Lechner S, Mattesich M, Kaiser A, Probst D, Wenger N, Pierer G, Zwerschke W. DLK1(PREF1) is a negative regulator of adipogenesis in $CD105^{+}/CD90^{+}/CD34^{+}/CD31^{-}/FABP4^{-}$ adipose-derived stromal cells from subcutaneous abdominal fat pats of adult women. *Stem Cell Res* 2012; **9**: 35-48 [*RCA*] [PMID: 22640926 DOI: 10.1016/j.scr.2012.04.001] [FullText]

55 **Hudak CS**, Gulyaeva O, Wang Y, Park SM, Lee L, Kang C, Sul HS. Pref-1 marks very early mesenchymal precursors required for adipose tissue development and expansion. *Cell Rep* 2014; **8**: 678-687 [*RCA*] [PMID: 25088414 DOI: 10.1016/j.celrep.2014.06.060] [FullText]

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