The relative influence of two different teaching strategies on the academic performance of a group of undergraduate radiography students in anatomy studies

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification

H J Boshoff

Date: December 2016

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ABSTRACT

A three-year National Diploma in Radiography course is offered at the Cape Peninsula University of Technology (CPUT). Anatomy is a one-year subject in the first year of the course. A radiographer must know theoretical anatomy in order to place a patient in certain positions to best illustrate the anatomy on x-ray images and to evaluate the images anatomically and technically to ensure a correct diagnosis. The main purpose of teaching and learning of anatomy to radiography students is for them to understand and know the theoretical anatomy, to be able to apply it clinically and to evaluate it radiographically.

However, a question arose why students at CPUT do not perform academically well in anatomy studies.

Although many factors can influence students' academic performance, the aim of this study was to investigate which teaching strategy, namely, team-based learning (TBL) or lecturing will have a greater influence on students' academic performance in anatomy studies.

A quasi-experimental research design was employed to generate quantitative data on 40 first-year radiography students' academic performance in anatomy while comparing TBL and lecturing.

The generated data were analyzed and the findings indicated that TBL had no significant influence on students' academic performance. The implications from the study as well as possibilities for future research are pointed out.

The study does however prove that TBL provides a more engaging learning environment for students when compared to lecturing and, therefore, has the potential to enhance radiography education with active student-centered teaching and learning.

OPSOMMING

‘n Drie-jaar Nasionale Diploma in Radiografie word by die Kaapse Skiereiland Universiteit van Tegnologie (KSUT) aangebied. Anatomie is ‘n een-jaar-vak wat in die eerstejaar van die kursus aangebied word. ‘n Radiograaf moet teoretiese anatomie ken om ‘n pasient in bepaalde posisies te plaas om die anatomie op die x-straalbeelde te illustreer en dan die beelde anatomies en radiografies te evalueer om te verseker dat die pasient korrek gediagnoseer word. Die hoof doel van die onderrig en leer van anatomie vir radiografie studente is dus vir hulle om teoretiese anatomie te verstaan en te ken, om dit klinies toe te pas en radiografies te evalueer.

‘nVraag het egter ontstaan hoekom studente by die KSUT nie akademies goed vaar in anatomie nie.

Alhoewel baie faktore studente se akademiese vordering kan beinvloed, was die doel van hierdie studie om te ondersoek watter onderrig-strategie, ‘team-based learning’ (‘TBL’) of formele lesings ‘n groter invloed op die student se akademiese vordering in anatomie sal he.

‘n Kwasi-eksperimentele navorsings-ontwerp is met 40 eerstejaar radiografie studente gebruik om kwantitatiewe data te genereer vir studente se akademiese vordering in anatomie wanneer ‘TBL’ en klas-onderrig vergelyk word.

Die data is ontleed en die bevindings dui daaropdat ‘TBL’ geen beduidende invloed op studente se akademiese vordering gehad het nie. Die implikasies van die studie asook moontlike toekomstige navorsing is uitgewys.

Die studie het egter bewys dat ‘TBL’ ‘n meer betrokke studie-omgewing vir studente bied wanneer ‘TBL’ met klasonderrig vergelyk word en dus die potensiaal het om radiografie onderrig te verbeter met aktiewe student- gesentreerde leer en onderrig.

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CHAPTER 1

ORIENTATION AND BACKGROUND

1.1 INTRODUCTION

The main aim of this study was to determine the relative influence of two different teaching strategies, namely team-based learning (TBL) and lecturing, on the academic performance of a group of undergraduate radiography students in anatomy studies. This was done in order to determine whether students' academic performances in anatomy studies could be improved.

One secondary goal of the study was to explore the first year radiography students' perceptions of engaging with TBL and the potential usefulness of TBL as a future teaching strategy. A second goal was to ascertain whether academically weaker students identified by their examination grades might benefit more from the use of TBL.

The focus during the study was on TBL as an innovative teaching strategy as its use has not been reported as a teaching strategy for radiography.

Chapter 1 describes the background to this study and provides for an understanding of the context in which the study was conducted. The research problem, the aims of the study and the research methodology, including the data collection and analysis, are briefly discussed. The chapter concludes with the outline of the rest of the thesis.

1.2 BACKGROUND TO THE STUDY

Academic performance measures the extent to which a student has achieved specific educational goals as stipulated by a higher education institution (Daly, Witt, Martens & Dool, 1997). Different teaching strategies can influence academic performance, but anatomy teaching strategies are widely debated and remain controversial to the present day. A key issue is how best to teach anatomy for knowledge retention and application (Kerby, Shukur & Shalhoub, 2011; McLachlan, Bligh, Bradley & Searle, 2004). Many authors have expressed opinions that anatomy teaching is 'in crisis', 'eroded and irrevocably changed' and 'demised' (Linacre, 2005; Standring, 2009; Raftery, 2006).

Traditionally, anatomy was taught by lectures together with whole body cadaver dissection and personal tuition (Older, 2004). This was a time-consuming process, for example, until the 1970s' medical students in Australia spent as many as 700 hours dissecting cadavers (Parker, 2002). This teaching method was also expensive in terms of floor space, the preparation of the cadavers and the number of teaching staff required (Older, 2004).

Except for the cost, various other events took place that caused a shift from this particular model of teaching. Serious considerations for a change in anatomical teaching were affected by issues such as significantly decreasing the teaching time for anatomy, the loss of experienced anatomy teachers, an increase in the number of anatomy students and the unavailability of cadavers due to ethical reasons (Louw, Eizenberg & Carmichael, 2009; Azer, 2011; Standring, 2009). According to Older (2004) further criticisms, like a too crammed curriculum with clinically unconnected facts, excessive memorization and passive learning were directed at the lecture method as a teaching strategy.

It is beyond question that anatomical knowledge is a requisite for safe clinical practice (Fasel, Morel & Gailloud, 2005), but it is reported that there is a dramatic reduction in the amount of anatomical content taught, and that healthcare professionals experience a decline in anatomical knowledge (Nicholson, 2005; Smith, Martinez-Alvarez & McHanwell, 2013). This is worrying, as it implies that healthcare professionals do not have adequate knowledge of anatomy to treat patients with a reasonable standard of care (Berlin, 1996). This can lead to increased medico-legal litigation which is one of the many challenges the medical profession has faced over the years worldwide.

In the United Kingdom between 1995 and 2000 medical claims associated with anatomical errors increased sevenfold, and the reason for the increasing medical errors is the decline or lack of anatomical knowledge (Older, 2004; Raftery, 2006; Bergman, van der Vleuten & Scherpbier, 2011). Thus, it seems that accurate anatomical knowledge is vital to ensure safe clinical practice (Bergman et al. 2011; Herle & Saxena, 2011).

A sharp increase in medical malpractice litigation is also reported in South Africa as patients increasingly become aware of their rights. The Gauteng Health Department faced negligence claims of R1.28 billion for the 2012/2013 financial year compared to 2009/2010 financial year when malpractice claims were R573 million. Most of these claims were related to misdiagnosis, practicing outside the scope of practice and negligence caused by nurses' poor training and attitudes (Malherbe, 2013; Child, 2014).

Malpractice suits in radiology mostly include failure to diagnose, incomplete knowledge, poor judgement or inadequate positioning of the patient and inadequate exposure of the image (Berlin, 1995; 1996). Poor quality images (x-rays) also increase the likelihood of missing a lesion (Berlin, 1995; 1996).

All these challenges and the increasing demands on healthcare professionals such as staff shortages, governmental and general public demands for higher levels of care and high costs (Anderson, 2010) made it clear that anatomy content and teaching strategies had to be evaluated to be adapted in order to equip healthcare professionals better for clinical work (Jackson & Calman, 2006).

Two challenges emerged to take center stage for changing current teaching strategies for anatomy. The first challenge is to take the students from passive learning to an active and engaging learning environment, where the curriculum is learner-centered and driven by learner needs (Mann, 2011). In the process, the role of the teacher alters from a provider of information to a facilitator of learning (Mirecka, 2000).

Theoretical anatomy knowledge is a key component in healthcare professionals' courses (Raftery, 2006) and presents the second challenge to curriculum relevance and application in teaching anatomy. Students will be motivated to learn when they understand the relevance of material and when they are required to apply the knowledge in a professional setting – where students often describe it as 'parts coming together' (Smith et al. 2013). Louw et al. (2009) describe theoretical knowledge as understanding concepts such as the structure of bones and the clinical application as experienced in practice such as bone fractures.

Taking these challenges into consideration, the traditional lecture method and cadaver dissection have been replaced by more recent approaches such as problem-based learning, computer-aided teaching and the use of pro-sections and plastic models (Older, 2004; Raftery, 2006). However, studies showed that medical students and professional anatomists prefer the use of cadaver dissection above other teaching methods (Kerby et al. 2011; Patel & Moxham, 2008; Moxham & Moxham, 2007).

At an institutional level, the three-year National Diploma in Radiography at the CPUT consists of theoretical and clinical components. Anatomy is a one-year subject in the first year of the course. Radiographers must know theoretical anatomy (see Figure 1.1) to clinically place a patient in certain positions (see Figure 1.2) and to best illustrate the anatomical structure on x-ray images (see Figure 1.3). They must be able to evaluate the images anatomically and technically to ensure the necessary anatomy is illustrated for a doctor to make a diagnosis. If a radiograph cannot be interpreted by a doctor because of poor positioning of the patient, a repeat radiograph must be done immediately (Berlin, 1995; 1996). This contributes to the patient's radiation dose that has to be must be kept as low as possible and it also increases the cost of the examination.

The main purpose of teaching anatomy to radiography students is thus for them to understand and know the theoretical anatomy, to be able to apply it clinically and to evaluate it radio-graphically.

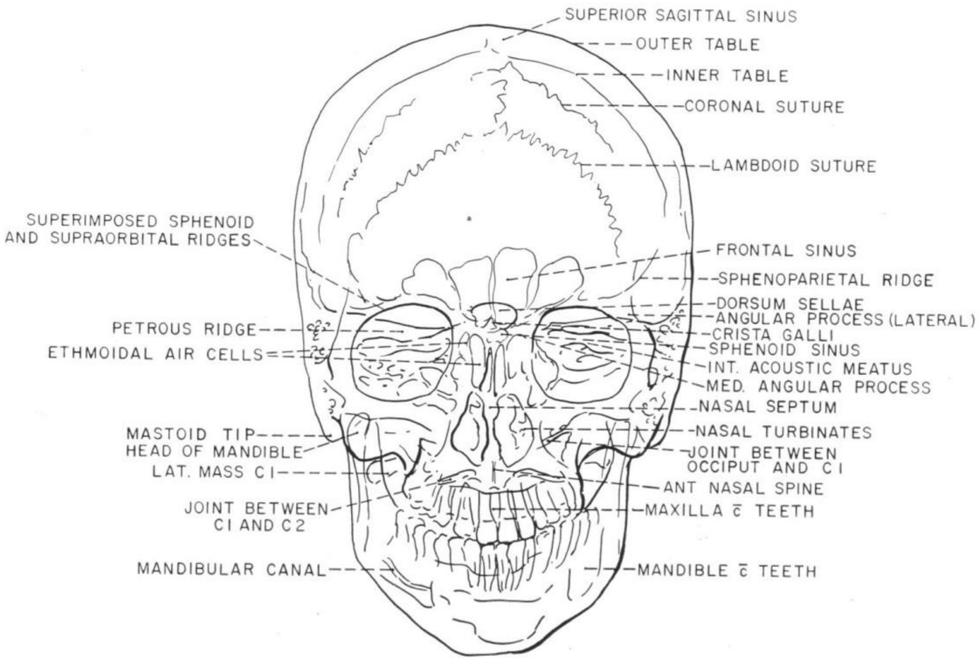

Figure 1.1: Straight posterioanterior view of skull: anatomy (Meschan & Ferrier-Meschan, 1968)

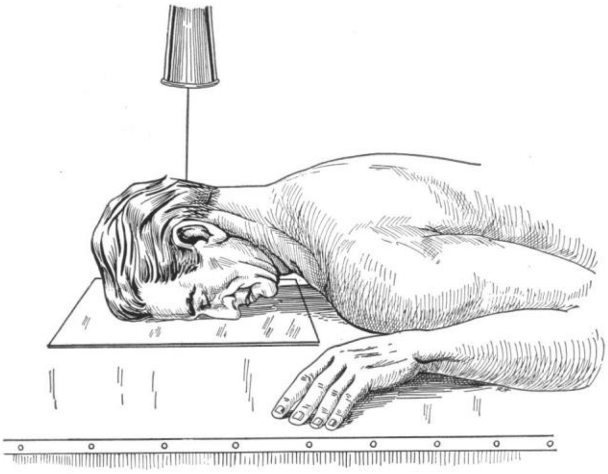

Figure 1.2: Straight posterioanterior view of skull: positioning of patient (Meschan & Ferrier-Meschan, 1968)

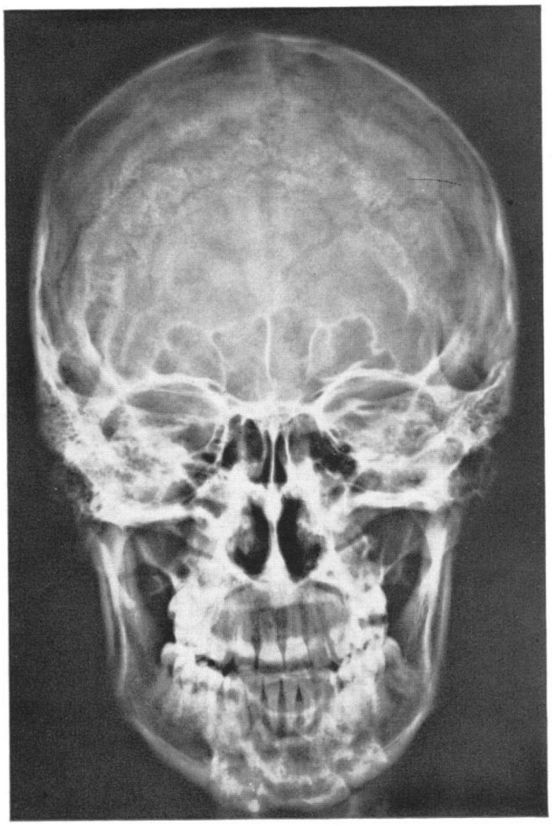

Figure 1.3: Straight posterioanterior view of skull: radiograph (Meschan & Ferrier-Meschan, 1968)

For many years theoretical anatomy for first-year radiography students was taught by means of the lecture method and PowerPoint® presentations. Lecturing, one of the most commonly used teaching strategies, unfortunately creates a passive learning environment, non-participation and encourages memorization and surface learning (Di Leonardi, 2007; Jones, 2007). However, large amounts of content can be covered with the lecture method, which is not always possible with other teaching strategies (Di Leonardi, 2007).

Curriculum content, which is often almost unmanageable, is mostly concentrated on form and structure and little attention is paid to the clinical relevance of such theoretical information (Van Engelshoven & Wilmink, 2001). However, when the students work in the clinical departments, they must apply the theory to clinical examinations to produce x-ray images and to evaluate the images in terms of the anatomy. This is difficult for first-year students because they do not know the theory and do not have sufficient opportunities to practice theory application. Thus, first-year students are not able to do applications successfully.

Anatomy theory is tested four times a year with written tests - mostly for recall of facts, which in most instances leads to rote learning and memorization of facts. Clinically, anatomy assessment is integrated in clinical evaluations of patients and an Objective Structured Clinical Examination (OSCE), where radiographic anatomy is assessed. According to the theory test results, the clinical evaluations marks and the students' own admissions students lack anatomical knowledge and experience problems with the application of knowledge.

This poor academic performance can be due to insufficient teaching time, too little hands-on practice, too much content, no laboratory facilities and a lecturer to student ratio of 1:40. The students who fail anatomy must first repeat anatomy before they can proceed to the second year. This has huge financial implications for students and their families. Also for a course where students must have a clinical placing to do the course, failures have implications, because students who failed can lose their placements in the clinical department. Ideally, however, lecturers prefer to qualify students with much more than a score of 50% for competency.

It became clear to the researcher, being an anatomy lecturer as well as an educational researcher that it is important to determine the best possible teaching strategies to fulfil the following criteria:

- students must take more responsibility for learning anatomy

- more regular testing of content to identify academically weaker students in time for an intervention is essential;
- students should be exposed to opportunities to practice application of theoretical anatomy
- an engaging learning environment should be created; and
- students should be enabled to perform better academically.

When searching for a better teaching strategy, it is important to pay attention to what Fink and Parmelee (2008) call the three 'daunting' challenges in modern medical education. These challenges are that

- anatomy is a content-laden subject and the content increases annually;
- students should learn how to apply the information in different clinical contexts, and that
- the learning process should promote good people skills like teamwork and communication.

These factors ideally need to be taken into consideration when implementing a different teaching tool.

TBL addresses most of the requirements and challenges as mentioned above. It is a student-centered, active learning strategy that engages students in their learning by utilizing small-group interaction (Parmelee, 2008). Michaelsen developed TBL in the late 1970s when he was an academic staff member at the University of Oklahoma and was confronted with the challenge of teaching a business course to a class of 120 students. He had used group activities in smaller classrooms, but he was at the time facing a class that tripled in size. Instead of using traditional lectures, Dr Michaelsen decided to rather use class time for group learning. He thus refined the TBL strategy that is increasingly used in medicine and law (Fink & Parmelee, 2008).

Although no evidence could be found of TBL being used in radiography, research in other disciplines such as nursing has shown that this strategy promotes critical thinking, communication skills and problem solving skills, which are necessary in education of health care workers (Clark, Nguyen, Bray & Levine, 2008).

1.3 RESEARCH PROBLEM

Teaching anatomy to radiography students presents two major problems. The first problem is that the students do not manage to know the theoretical anatomy facts and they are not able to apply the theoretical knowledge to different clinical scenarios. There is often a misperception that the theoretical knowledge that students are taught in formal lectures, makes them competent to apply the theoretical knowledge clinically in order to treat patients optimally. However, the application of theoretical knowledge is a learnt skill and students rather need to be given opportunities to practice within realistic contexts to become competent professional health care specialists.

The second problem is that the traditional lecture method mostly creates a passive learning environment, which is regarded as not conducive to learning.

Many factors can influence learning and in this study the relative influence of two different teaching strategies in order to help students learn factual anatomy and its application were investigated. Lecturing was compared to TBL as teaching strategy – the latter whereby students were required to take responsibility to learn anatomy content themselves and then given opportunities to apply the theory to clinical situations, while working in groups in an active learning environment.

Thus, the study aimed at determining the relative influence of the two different teaching strategies on the academic performance of undergraduate radiography students in anatomy studies.

1.4 THE AIM OF THE STUDY

The aim of the study was to determine the relative influence of two different teaching methods, TBL and lecturing, on the academic performance of a group of undergraduate radiography students in anatomy studies.

1.5 RESEARCH QUESTIONS

1.5.1 Primary research question

The primary research question for this study was stated as:

> *Which teaching strategy, TBL or lecturing has the greater influence on the academic performance of radiography students in anatomy studies?*

1.5.2 Secondary research questions

The secondary research questions that supported the main research question were formulated as:

- Does a switch to TBL have an effect on the performance marks of radiography students as identified by their examination results?
- How do first-year radiography students view the potential of TBL for learning anatomy?

1.6 RESEARCH DESIGN

To address the research questions of this study, a quasi-experimental research design was employed to generate quantitative data on student academic performance as well as gather their perceptions of the potential usefulness of TBL.

In Chapter 3 the research methodology and design are described and discussed in detail.

1.6.1 Study participants

Forty first-year radiography students (N=40), attempting their anatomy studies for the first time, participated in the study. This existing student group was randomized into two groups of twenty-two (n=22) and eighteen students (n=18) respectively. The full-time lecturer responsible for teaching anatomy was also the researcher and facilitator of the study.

1.6.2 Data collection

The quantitative data were generated by using pre- and post-tests scores as a measurement tool as well as self-reported feedback questionnaires. The pre- and post-tests were the same tests in content, consisting of forty multiple-choice questions, covering the anatomy of the two learning outcomes (twenty multiple-choice questions for the anatomy of the wrist and twenty multiple-choice questions of the anatomy of the elbow).

The data on the perceptions of the first-year radiography students of their engagement with TBL and their opinions about the usefulness of TBL as a future teaching tool were generated with a self-reported feedback questionnaire.

1.6.3 Data analysis

A statistical analysis, t-tests and ANOVA, was applied to the quantitative data to detect whether there were statistical significant differences between the pre- and post-test scores for the two student groups.

The quantitative data were analyzed with descriptive statistics according to the feedback questionnaire questions completed by the participating students.

1.7 ETHICAL CONSIDERATIONS

The participants were notified and informed concerning the reasons for the study as well as the conditions of participation and their rights regarding participation (Leedy & Ormrod, 2010). The participants were also given the choice to participate in the study. Informed consent forms (see Addendum A) were signed, while anonymity was assured. The data were used for the sole purpose of the research, remained confidential and kept locked in a safe place and will be destroyed after the study has been completed.

Ethical clearance was granted by the Ethical Committee for Human and Social Sciences at Stellenbosch University as well as the Research Ethics Committee at CPUT (see Addendum B).

1.8 CONCLUSION

In summary, the first chapter serves as an orientation to the study and includes the background to and a motivation for the study. The aim, research design and ethical considerations of the study were accounted for.

The rest of the study report will be structured as follows:

Chapter 2 consists of the literature review, followed by the methodology of the research in Chapter 3. The research findings are reported in Chapter 4 and the conclusions and implications of the findings are discussed in Chapter 5.

CHAPTER 2

THEORETICAL PERSPECTIVES

2.1 INTRODUCTION

More than twenty years ago, Robert Barr and John Tagg (1995), in their internationally recognized article campaigned for a "paradigm shift" in American higher education. They stated that instead of providing teaching, a higher education institution should produce learning in order for students to take responsibility for their own learning.

One of the challenges in medical education is to identify teaching and learning strategies that will produce learning rather than teaching. For years a debate has been ongoing about the core curriculum in the subject of anatomy that healthcare professionals need to practice safely. Simultaneously, the mode of delivery to ensure deep learning of anatomy and to link factual anatomy to living anatomy as found in patients is also widely debated (Kerby et al. 2011; Beers & Bowden, 2005).

The primary objective of this study was to determine the relative influence of two different teaching strategies, team-based learning (TBL) and lecturing, on the academic performance of a group of undergraduate radiography students in anatomy studies. The first secondary objective was to explore the first-year radiography students' perceptions of their engagement with team-based learning and the potential usefulness of team-based learning as a future teaching strategy. The second was to ascertain whether academically weaker students identified by their examination grades might benefit more from the use of team-based learning.

This chapter deals with relevant literature regarding different modes of teaching or teaching strategies in facilitating student learning. Relevant literature is explored by discussing traditional lecturing and TBL as teaching strategies, as well as the comparison between TBL, lecturing and other teaching strategies. The chapter will conclude with the use of TBL and lecturing to teach and learn anatomy.

2.2 THE TRADITIONAL LECTURE AS MODE OF TEACHING OR LECTURING STRATEGY

The traditional lecture has been the most common, well-known and widely used teaching strategy in medical education and other disciplines (Lake, 2001; Gulpinar & Yegen, 2005; Di Leonardi, 2007; Kamei, Cook, Puthucheary & Starmer, 2012; Diaz & Woolley, 2015). A lecture normally lasts 45 to 60 minutes with one lecturer and a large group of students in one venue (Ludmerer, 2000; Beers, 2005; Miller, 2003) with the aim of conveying a large amount of information in the shortest possible time (Weatherall, 2011). The lecturer usually provides the information verbally, which may include hand-outs and/or visual aids (Johnston & Mighten, 2005), although Young (2009) argues that a lecture with the use of, for instance, PowerPoint® is the most boring way of teaching. In lecturing the lecturer is in control of the learning environment, controls the content and the pace of conveying the information, which can leave the students feeling overwhelmed (Di Leonardi, 2007; Goffe & Kauper, 2014).

Lecturing essentially represents passive processes (Young, 2009), which offers students mainly non-participatory roles in the learning process (Di Leonardi, 2007; Jones, 2007). Traditional lecturing lacks student-lecturer interaction (Adams & Gilman, 2002) and does not allow for high levels of student engagement (Di Leonardi, 2007), which according to Graffam (2007), is essential components of good education. Students are encouraged to simply memorize for short-term recall, but with little understanding of the subject or how to apply the knowledge (Leinster, 2002; Di Leonardi, 2007). Martin (2013) states that lecturers must distinguish between what they want the students to know versus what the students must understand what it is that they are being asked to do. Lecturing therefore can easily lead to surface learning if the aim is merely to transmit information to students (Di Leonardi, 2007; Jones, 2007).

During lectures, students will often have few or no opportunities to apply knowledge, which mostly results in a lack of deep learning. Deep learning is usually best achieved by the student actively constructing knowledge through experience (Jones, 2007). This active construction of knowledge leads to increased levels of learning and understanding, which provides students with better options of applying their knowledge (Goffe & Kauper, 2014).

In health professions education in particular, the passive nature of the lecture may thus prevent the students from the kind of learning that will prepare health care professionals for the complex nature of patient conditions that they are required to treat in the clinical departments (Weatherall, 2011). Lecturing can easily stunt the development of critical thinking skills, because when applying knowledge in simulated clinical settings, the student practices critical thinking (Adams & Gilman, 2002). According to Ludmerer (2000) the objective of medical education is to produce problem-solvers and critical thinkers, instead of rote memorizers.

Courts and McInerney (1993) as cited in Fink (2003) reported that students are most commonly concerned when lecturers primarily rely on lectures and workbook exercises to transmit information, but ironically the same report found that students do not see themselves as self-directed learners. In research it was reported that students saw lecturing as requiring less time, commitment and effort (Opdecam, Everaert, Van Keer & Buysschaert, 2014). Many students also expected lecturers to cover all the important and relevant information during a lecture, which will allow them to pass the course (Young, 2009).

Traditional lectures do not create a relaxed, interactive and stimulating teaching and learning environment for lecturers and students (Adams & Gilman, 2002). Although the lecture seems to be a poor choice for active learning and to be outmoded as a teaching strategy (Smart, Witt & Scott, 2012) it does have valuable assets.

Lectures play a role with regard to clarifying difficult concepts, to provoke thought, to present different perspectives on a subject and to motivate students to learn (Johnson & Mighten, 2005; Brown & Manogue, 2001). In an era where cash-strapped universities will always weigh the costs against the benefits, lecturing is cost-effective and efficient in terms of time, the number of personnel required and venues (Goffe & Kauper, 2014; Ludmerer, 2000).

2.2.1 Comparing the traditional lecture to other teaching strategies

Multiple research studies comparing the traditional lecture to other teaching strategies have been conducted, although the findings do not always provide clear results. The studies where lectures are compared with different active teaching strategies will be reviewed to point out the potential effect on student academic outcomes, student reactions and critical thinking.

2.2.1.1 *Student academic outcomes*

Miller (2003) has set out to determine how students' academic performance would be influenced when comparing an active teaching tool, problem-based learning (PBL) and lecturing as a teaching strategy. In Miller's study a small sample of 22 nurses were taught on a pharmacology course. The control group that were taught via lectures consisted of 12 students and the experimental group for PBL had 10 students. The student academic performance was tested in a final examination. The results showed no significant difference in the academic performance between PBL and the lecture group, suggesting that the PBL and lecture strategies may be equally effective in promoting content learning by students. This was a surprising finding, but the author argued as a possible explanation that the students were used to lectures and not familiar with PBL.

Another study (Beers, 2005) also showed no significant difference in student academic performance when the effect of PBL versus lectures was investigated on objective test scores of 54 nursing students. A pre- and post-test design of ten multiple choice questions was used for both groups. Thus, there was no difference in academic performance based on the relevant teaching strategy. However, the author offered no explanation for the outcome of the study.

In a follow-up study, one year later, Beers and Bowden (2005) re-evaluated the same group of 54 nursing students to test their long-term knowledge retention after experiencing TBL and lectures. The same post-test was used and the students in the PBL group showed significantly higher scores than the lecture group. This research was unique in its attempt to address long-term knowledge retention when comparing active and passive learning. The authors also cited limitations, for instance that the study used a single setting with limited learning material tested.

The findings of the next four studies in contrast with the findings of Miller (2003) and Beers (2005) showed improved academic performance for active teaching methods, which is more in line with what relevant literature reports in general.

Lake (2001) compared the lecturing strategy with the strategy of small group discussions. A sample of 170 first-year physiotherapy students was used and their academic performance was tested with an examination. In this study small group learning as an active teaching-learning strategy resulted in higher student academic performance when compared with the lecture-only method.

Haidet, Morgan, O'Malley, Moran and Richards (2004) reported similar results when students who experienced active learning strategies had higher performance scores. A sample of 82 medical residents was used with 27 residents in the lecture group and 36 in the active learning group. The lecture was 60 minutes long with one lecturer lecturing and showing slides. The experimental group for active learning was divided into groups of four to five students and each group was given tasks to solve and then a class discussion about the tasks and possible solutions followed. The session ended with a 30 minute lecture summarizing the content. There were three knowledge assessments, before, after and one month later. The tests consisted of true/false and multiple choice questions (MCQs). Students from the active learning group showed improved academic scores compared with the lecture method group. An important observation was that with the active learning strategy, the amount of time spent on lecture content delivery was reduced by 50%. The same amount of content with no detrimental effect on knowledge was covered, which could be translated into a significant cost saving.

Johnson and Mighten (2005) compared a traditional lecture group and a group of students using lecture notes and structured group discussions. The comparison of the examination scores of 169 undergraduate nursing students showed significant differences. The results provided strong support for the use of lecture notes in conjunction with structured group discussions as a teaching strategy.

Costa, van Rensburg and Rushton (2007) conducted a randomized trial with 77 fourth-year medical students to evaluate group discussion as active learning versus lectures in terms of use and knowledge retention. The students in the interactive discussion group performed better on a written test, which led to the conclusion that student academic performance was better with active learning methods. The researchers agreed that the financial and resource cost of providing students with interactive group discussions can be an issue, but was not addressed in the research.

2.2.1.2 *Student responses*

Pugsley and Clayton (2003) studied students' attitude regarding different teaching strategies. In an attempt to enhance students' appreciation of nursing research, the authors added an experimental learning course to the traditional lecture course. The experimental course consisted of a hands-on problem-solving activity and a mini research project that both had to be done via group work. Then the individuals critiqued articles, which was followed up by a class discussion. Twenty-five junior level nursing students in the experimental group and 19 senior level nursing students in the traditional lecture group completed a 15-item survey questionnaire using a 5-point Likert scale. The results showed that the students in the experimental learning group exhibited significantly more positive attitudes towards nursing research than the students in the passive lecture group.

As part of the research of Costa et al. (2007) the level of satisfaction of the students in terms of the lecture or the interactive discussion group was measured. The results showed the students indicated higher levels of satisfaction with the active learning strategies that supported the findings of Pugsley and Clayton (2003). The level of student satisfaction was also measured by Miller (2003) and showed that the students had the same level of satisfaction with lectures and PBL.

Although the studies of Haidet et al. (2004) and Lake (2001) showed that active learning led to better knowledge scores, the students perceived to have learnt less with active learning.

In yet another study, Moein and Seraj (2014) compared the viewpoints of 102 medical students about the effectiveness of their participation in group discussions versus lectures. They concluded that the students saw group discussions as a valuable strategy that required all the students to participate and resulted in a deeper understanding of the subject.

2.2.1.3 *Critical thinking*

The aim of a study by Tiwari, Lai, So and Yuen (2006) was to compare the effects of PBL and lecture approaches on the development of students' critical thinking. Seventy-nine first year undergraduate nursing students were surveyed over one academic year. The students who participated in PBL had significantly higher overall critical thinking scores on completion of the course compared with the students who received lectures. The students from the PBL group continued to have higher scores than the students from lectures for two consecutive years, although to a lesser degree.

Reviewed research articles comparing traditional lecturing to other teaching strategies mostly indicated positive results with regard to student academic performance and student reactions in favor of teaching strategies other than lecturing. These findings support the view that traditional lectures may not be the most effective teaching strategy, especially in terms of deep learning and retention (Jones, 2007; Di Leonardi, 2007).

2.3 TEAM-BASED LEARNING AS TEACHING STRATEGY

The idea of TBL originated with Larry Michaelsen in the late 1970s. The primary objective of TBL is not simply covering the course content, but to focus on ensuring that students have opportunities to practice using course content to solve problems (Fink & Parmelee, 2008; Michaelsen & Sweet, 2008).

TBL is a learner-centered strategy with critical lecturer input for small group active learning in large group settings. TBL consists of three key components: first the students do individual advance preparation of course material, then the students come to class to take short tests on their understanding of the advance preparation materials – the tests are taken first individually and then in teams and afterwards the majority of in-class time is spent doing decision-based high-level application assignments in teams. Grading, peer evaluation and immediate feedback promote individual and team accountability to facilitate learning (Parmelee, Michaelsen, Cook & Hudes, 2012).

TBL is different from traditional lectures, as the focus of class time shifts away from content or information delivery to students who actively help each other to learn how to apply content (Michaelsen & Sweet, 2011). Malone and Spieth (2012) found that switching to TBL has the potential for better understanding of material and better long-term retention of knowledge through application practice. It also converts the ever expanding course material into a format that encourages more active and deeper learning, while not necessarily increasing the students' workload.

In traditional courses students are accountable to the lecturer, but in TBL the students are accountable to both the lecturer and their peers (Cestone, Levine & Lane, 2008). Accountability is regarded as a "cornerstone" of success of TBL. The individual students, the teams and the lecturer are accountable to promote learning. Students must prepare before coming to class, attend class and work effortless in their teams. The lecturer must provide the preparatory knowledge foundation and the opportunities to practice applications of the knowledge (Parmelee & Michaelsen, 2010).

TBL uses peer evaluation, Readiness Assurance Tests (RATs) and feedback to increase team members' accountability to one another and to develop the teams' abilities (Michaelsen & Sweet, 2011; Michaelsen & Sweet, 2008).

One of the most prominent hurdles in TBL seems to be student resistance and students' attitudes about advance preparation for class (Parmelee, Michaelsen, Cook & Hudes, 2012 ; Lane, 2008). Other factors include that students will see themselves as doing all the work by 'teaching themselves' while the lecturer 'is not teaching'. Some students might also have had bad experiences with group work (Parmelee & Michaelsen, 2010; Lane, 2008; Thompson, Schneider, Haidet, Perkowski & Richards, 2007), but when students show willingness to share the responsibility for learning, the TBL process can be fun (Lane, 2008; Fink & Parmelee, 2008). Thus, it is essential to get 'buy-in' from students and academic staff to make TBL successful (Kendal-Wright & Kasuya, 2010). In order to get the effort from everybody, the students and academic staff have to understand why TBL will be used and how TBL is designed to avoid problems they might have experienced with previous group work (Parmelee & Michaelsen, 2010).

Other than accountability, decision making is another fundamental element of TBL. The structure of TBL during application exercises requires individuals and teams to make decisions, therefore teaching students about judgement based on the content of the subject (Parmelee et al. 2008) seems crucial.

The first step to successfully implementing a TBL course should be taken well before the course begins. Important decisions are needed with regard to the design (Michaelsen & Sweet, 2008). The transition from traditional teaching to using TBL can be made easier if lecturers participate in training workshops on TBL and make use of teaching and learning advisors experienced in TBL, and who can critique materials to help with solving design and implementation problems. All module materials, multiple-choice questions and application assignments can be peer-reviewed (Parmelee, et al. 2012).

Learning outcomes for traditional teaching methods such as lecturing are derived from the question, 'What do we want the students to know?' TBL, however, derives desired learning outcomes from the question, 'What do we want the students to be able to do with this information?'(Parmelee, 2010). This involves a mind shift from traditional education, where knowledge acquisition is usually separated by a time lapse to the application of the knowledge to TBL that fundamentally allows knowledge application directly after knowledge acquisition (Michaelsen & Sweet, 2008).

Therefore, designing a TBL course requires lecturers to 'think backward', because they must identify learning outcomes around what they ultimately want students to be able to do when they finish the course. Only then do lecturers seem to think about what the students need to know (Michaelsen & Sweet, 2008). Parmelee and Michaelsen (2010) stated that this is often the most difficult question for lecturers who are content-driven to ask themselves.

The backward design of TBL consists of three stages. Initially, clear and meaningful learning goals have to be defined, then feedback and assessment activities are designed and finally, the teaching and learning activities are planned (Parmelee et al. 2012). The course is divided into units, usually four to seven, each unit with advance preparation materials, RATs and application exercises (Dana, 2007). The preparation of educational materials for the TBL approach requires a large amount of time and considerable development on the side of academic staff (Parmelee, 2010; Ortega, Stanley & Snavely, 2006).

Before the implementation of TBL, a credible system for allocating marks has to be designed. The design must ensure that the correct learning behaviors are rewarded. An effective grading system thus provides incentives for both individual and teamwork. As there are always concerns about the fairness of a grading system, a significant proportion of the grade in TBL is based on individual performance, team performance and each student's contribution to the success of the team. Involving students to discuss the grading system and to participate in decisions about the weighting of each portion usually put the students' concerns to rest (Michaelsen & Sweet, 2008).

2.3.1 First day of class

Successful implementation of TBL in a course requires proper orientation of the students on the first day of class. The students must know why the lecturer will be using TBL and how the class will be conducted. Students are usually concerned about what the workload will be and what types of examinations will be given (Lane, 2008). The students will be resistant to the out-of-class preparation, but it must be made clear that class-room time will shift from time for knowledge transmission to time for problem-solving. The first few hours are critical to get the students' buy-in and to convince them of the learning advantages for them (Parmelee & Michaelsen, 2010). Parmelee et al. (2012) even suggested that the students do an orientation with TBL facts and information by for instance, doing advance preparation by reading about TBL and in-class RATs, covering the essential principles of TBL. The lecturer will then clarify concepts and explain the ways in which application assignments would work.

2.3.2 Team formation

The lecturer facilitates group formation at the beginning of the semester and as suggested by Michaelsen and Sweet (2011), the first essential element of TBL is permanent teams of five to seven students, which remain intact for the length of the course. Before team formation, the lecturer will investigate the students' profiles for diversity issues such as languages, rural or urban home settings and so-called 'wealth factors' such as previous work experience or advance degrees, spread over the groups (Parmelee & Hudes, 2012). It is important not to let the students self-select, but the team assignment process must be transparent – students should never wonder why they are assigned to a particular team (Parmelee et al. 2012). Teams must therefore be properly formed and managed to develop group cohesiveness and to ensure that the teams can develop into proper learning teams (Michaelsen & Sweet, 2008).

2.4 IMPLEMENTATION OF TBL

The TBL cycle consists of three phases as demonstrated in Figure 2.1. It starts with individual student pre-class preparations including the study of assigned materials (for example, readings from textbooks, viewing lecture videos, reading articles, doing own research and sharing information amongst team members). Once classes start, the readiness assurance process is completed. The in-class RATs process requires the students to take a short multiple-choice questions test about their understanding of the assigned pre-readings. For a start the students take the same test individually, which is the Individual Readiness Assurance Test (IRAT) and then again as a team, the Group Readiness Assurance Test (GRAT). These tests are designed to hold students accountable for phase one preparation and to help peer teaching in areas of deficiency. The teams receive immediate feedback and can write appeals with valid arguments to the lecturer to reclaim credit for incorrect answers. After the RATs process, the lecturer presents a short dedicated lecture to clarify any unclear concepts picked up during the RATs process.

During phase three of TBL, students complete one or more application exercises whereby they apply what they have learnt during the advance preparation and the readiness tests. This process happens in class time and repeats for each unit of instruction, usually five to seven times per course.

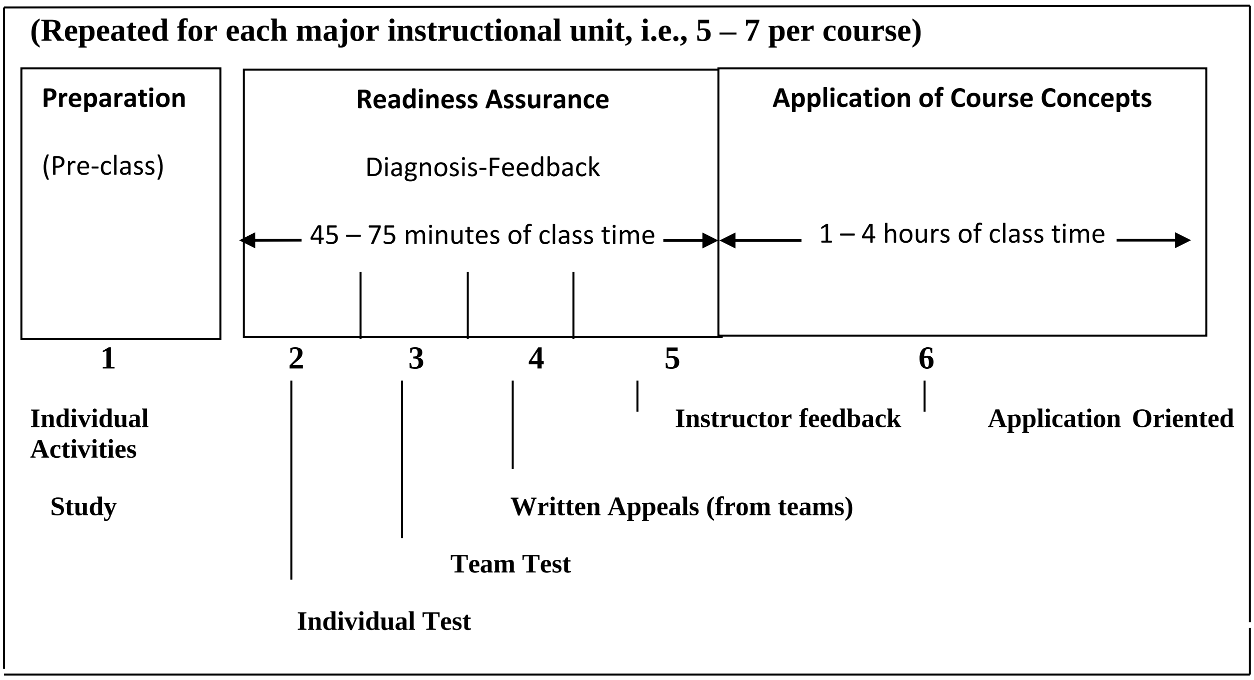

Figure 2.1: Team-based Learning Instructional Activity Sequence (Michaelsen & Sweet, 2008)

Students do peer evaluations for members of their team a few times during the course. In a typical TBL course students have to remain in their assigned teams for the duration of the course. This model was modified for this study due to time constraints.

To summarize, TBL is a highly learner-centered teaching strategy with academic staff input, grading, immediate feedback and peer evaluations to promote individual and team accountability and facilitate student learning (Parmelee, et al. 2012; Michaelsen & Sweet, 2008; Lane, 2008; Parmelee & Michaelsen, 2010; Parmelee & Hudes, 2012; Michaelsen & Sweet, 2011; Bahramifarid, Sutherland & Jalali, 2012; Thompson et al. 2007).

2.4.1 End of the TBL course

Towards the end of the course, the students must reflect on their experiences with TBL. Students may be nervous that they did not learn sufficient content, but if the lecturer, on an ongoing basis, point out the necessary content that has been weaved into the RAT and application assignments, it should put their minds at rest (Michaelsen & Sweet, 2008).

The majority of students' experience with group work is that some students do more than their share of work or deal with less motivated or less able team members. With TBL, however, the value of teams is illustrated by taking the scores of the individual and team tests into consideration. The teams will thus always outperform their own best member. Students also become aware of their interaction in a team and how they grow in group processes and effectiveness (Michaelsen & Sweet, 2008; Parmelee & Michaelsen, 2010).

2.5 TEAM-BASED LEARNING IN MEDICAL EDUCATION

The first reported implementation of TBL in medical education was done by Haidet, O'Malley and Richards (2002). They replaced a noontime lecture for internal medicine residents with a TBL exercise. They aimed to survey the residents' attitudes toward the usefulness of the content before and after the TBL session and also the residents' engagement in learning. The residents reported high levels of learner engagement and demonstrated significant effects on residents' attitudes about the usefulness of the content to their daily medical practice. At that stage it was concluded that TBL may be a useful new teaching tool in medical education (Haidet et al. 2002).

In 2003 an article about the initial experiences with TBL in ten medical schools was published (Searle, Haidet, Kelly, Schneider, Seidel & Richards, 2003). The paper reported initial reactions, responses and implementation efforts at the ten institutions. TBL was implemented in 40 courses and the amount of time spent doing TBL varied greatly, from one hour to complete courses. The most common type of response from 63% respondents was that academic staff and/or students had perceptions of satisfaction with TBL. Other responses were that students' academic performances were equal if not better when the course was taught with TBL, high levels of student engagement in the TBL process, but also concern about peer evaluations for grading purposes. All ten schools reported that they intend to expand TBL (Searle et al. 2003).

Two years after the use of TBL in the ten medical schools as described, these schools were again evaluated with regard to the implementation progress of TBL. The aim of the evaluation was to review the progress at these schools and if there were any factors affecting the use of TBL in the last two years. TBL use was discontinued in one school and in the other schools TBL was dropped from some courses, but added to other courses.

Certain factors influenced the implementation of TBL and had to be taken into account when a school wanted to start a TBL programme. These factors included the buy-in of academic staff with positive attitudes and exposure to TBL, usually through training workshops. It was also recommended that administrative support for coordination between courses was needed, and that the buy-in from students was important, as resistance to a perceived bigger workload and peer evaluation could be experienced.

It was thus again concluded that TBL as a teaching strategy had value for use in medical education (Thompson, Schneider, Haidet, Levine, McMahon, Perkowski & Richards, 2007).

2.6 COMPARISON OF TEAM-BASED LEARNING WITH OTHER TEACHING STRATEGIES

Research studies comparing TBL to other teaching strategies have been conducted, but the findings of these studies are not always consistent. A review study done to determine whether TBL increases knowledge scores and improve student satisfaction showed that the different studies had various methodological shortcomings in terms of randomization and TBL comparison with different teaching strategies. Of the 14 studies compared, seven reported a significant increase in knowledge scores, four studies showed no difference and three showed improvement, but did not comment on the statistical significance. All the studies showed mixed learner reaction (Fatmi, Hartling, Hillier, Campbell & Oswald, 2013). The studies that will be reviewed next, mostly involved the TBL effect on academic outcomes and student reactions.

2.6.1 Academic performance

A study by Koles, Nelson, Stolfi, Parmelee and DeStephen (2005) showed no significant difference in the students' academic performance when comparing TBL and case-based group discussions. A sample of 83 second-year medical students was used for eight pathology modules over a ten-month period. Their academic performance was measured by a pathology-based multiple-choice questions examination at the end of the course. Academic staff and student-related variables that can impact on the performance on MCQs were recognized, but although flawed, MCQs remain an acceptable method of assessing learning outcomes. It was thus concluded that both TBL and case-based group discussions were equally effective, because both represent active learning strategies and in this case showed no significant difference in academic performance.

One important observation was however made in the above study. Students in the lowest academic quartile showed better examination performance after the TBL process and reflected longer retention of knowledge. However, the longer retention of knowledge was not significant in all the pathology modules. A possible explanation can be that the modules had different levels of difficulty.

In contrast, research comparing case-based group discussion and modified TBL sessions showed a moderate difference in academic performance for TBL (Zgheib, Simaan & Sabra, 2010). A sample of second-year medical students was taught two sessions of pharmacology employing a case-based group discussion and modified TBL. Their academic performance was tested with a summative quiz. The increase in academic performance when using TBL in this study was subscribed to the fact that the TBL was modified and the students had selected their own groups. An important issue reported by academic staff in this project was the difficulty in developing an appropriate level of RAT questions as well as application questions to fit the content (Zgheib et al., 2010).

Two other studies showed moderate differences in academic performances of students (Thomas & Bowen, 2011). In an ambulatory medical clerkship course 112 second, third- and fourth-year students participated in small group lectures and TBL over a four-week block. Their academic performance was tested by written tests at the end of the course. A difference was observed in the test scores between the TBL and small group lectures cohorts with higher scores in favor of TBL. Reasons for the improved scores for TBL could be that more time was spent on the tasks as students had time to prepare advance material and spent time on content in class, whereas small group lecture sessions only had time for content discussions in the class. The RAT of TBL could also prepare the students better for the final written tests. Limitations of the study were that the course had one facilitator for both sessions, which could have led to bias for one specific teaching method and that the observation time of four weeks was insufficient to compare small group lectures and TBL. However, TBL was seen as a promising teaching tool for the future (Thomas & Bowen, 2011).

In contrast, two other studies showed significant higher academic scores for TBL when TBL and other teaching strategies were compared. In the first study, Wiener, Plass and Marz (2009) conducted TBL with 588 first-year medical students and an independent study with 829 first-year medical students for a year for the purpose of comparing student academic performances. A final examination was written to test the students' academic performances. The students participating in TBL sessions scored 18.3% higher than the students who studied independently. A contributing factor to this outcome could be the fact that the students elected themselves to do the TBL and thereby the experiment most probably attracted more motivated students. Another possible explanation was that the TBL exercises were too easy.

The second study used TBL and mixed active-learning methods for 64 students from pharmacology who did an elective course in Ambulatory Care (Zingone, Franks, Guirguis, George, Howard-Thompson & Heidel, 2010). Thirty-seven students were assigned to TBL and twenty-seven students to mixed active-learning methods. Eventually the students' grades were compared. Students in the TBL course earned 0.33 more quality points than the students in the mixed active-learning course, which indicated significantly higher academic performance for TBL students. The authors point out that reasons for this could be the difference in course structure and the evaluation methods used. The main difference in formal assessments was the quantity and type of content covered in each examination. Students usually perform differently with different assessment types and in this study the content of the assessments differed. The TBL course included the individual and team assessments, which could have inflated the grades, whereas for the mixed active-learning course, only the individual grades were used. The academic staff involved in this study recognized TBL as an effective and time-efficient teaching strategy (Zingone et al. 2010).

The results of research on academic performance seem to be inconsistent when TBL is compared with other teaching strategies, but in par.2.7 of the literature review, attention will be specifically paid to student academic performance when TBL is compared with traditional lectures.

2.6.2 Student responses

The studies referred to up until this point all investigated the students' reactions to TBL as a secondary outcome. In the study by Koles et al. (2005) where there was no significant difference in academic performance, the students showed no preference for one method and the overall satisfaction was the same for TBL and case-based group discussions. In a study by Zgheib et al. (2010) where the same teaching strategies as described earlier were compared the students provided positive feedback by stating they wanted more TBL in future. The study by Zgheib et al. (2010) showed moderate difference in academic performance and also showed that the overall usefulness as perceived by students was equal for TBL and small group lectures, but that the students pertinently showed appreciation for the value of teamwork. However, they indicated concern about peer evaluation (Thomas &

Bowen, 2011). In studies that showed the highest difference in academic performance as indicated by Zingone, et al. (2010), the students were satisfied with both teaching methods. In addition, Wiener, et al. (2009) reported that students were motivated by and engaged in TBL, but that they found the pace of the teamwork in general too slow.

2.7 COMPARISON OF TEAM-BASED LEARNING WITH THE TRADITIONAL LECTURE METHOD

Research studies comparing TBL with the lecture method in medical education with regard to students' academic performance and reactions will be discussed next.

2.7.1 Student academic performance

Studies comparing TBL and lecturing (Jafari, 2014; Persky and Pollack, 2011; Koles, Stolfi, Borges & Nelson, 2010; Letassy, Fugate, Medina, Stroup & Britton, 2008; Levine, O'Boyle, Haidet, Lynn, Stone, Wolf & Paniagua, 2004) all showed a significant difference in student academic performance when using TBL.

Jafari's (2014) study involved 70 neurology students over one academic year. The course content was divided into eight TBL sessions and eight lectures. The students' academic performance for the lecture sessions were tested with multiple-choice questions and the TBL sessions were graded with the IRAT and GAT scores. The results showed a significant difference in student academic performance when using TBL. The author suggests that various factors such as the effect of self-study and team cooperation in the learning process could be responsible for the better scores from TBL.

The same results were observed by Persky and Pollack (2011) when they replaced the lecture-format with TBL in a physiology course. A hundred and fifty-three first-year students wrote a knowledge-based examination after one year of TBL. These results were compared with the results from the lecturing mode of the previous year and showed a significant increase in academic performance with TBL. The authors indicated that this difference in performance could be the result of more student-lecturer engagement and the reinforcement with repetition that is part of the nature of TBL. Better communication skills and working as part of a team were also observed with the TBL process.

A hundred and seventy-eight second-year medical students did TBL for two years in a course that previously employed different teaching tools such as lectures and laboratory work

(Koles, Stolfi, Borges, Nelson & Parmelee, 2010). In a multiple-choice questions examination the students had higher scores with TBL. The researchers reasoned that the combination of advance preparation and the interaction with peers and lecturers could be a possible explanation for an increase in marks. An analysis of the student academic performance also revealed that lowest-quartile students had 7.9% higher scores with TBL than the highest-quartile students who achieved only 3.8% higher scores with TBL (Koles et al. 2010).

Findings from other studies conducted in the same manner by Letassy et al. (2008) and Nieder, Parmelee, Stolfi and Hudes (2005) supported the view that TBL provides a larger learning benefit for academically weaker students. Letassy et al. (2008) used 140 students to participate in lectures and 148 students for using TBL in an endocrine module with 13 TBL sessions. Students were tested with a written examination and those doing TBL had an average score of 86% over the lecture participating students with 81%. Again, maximum student accountability, participation and engagement with TBL were given as possible reasons for the more favorable examination marks for TBL.

Levine et al. (2004) conducted a large study with 306 third-year students in psychiatry. The course involved lecturing versus TBL, with 8 TBL sessions of which four were modified TBL sessions. During the modified TBL sessions lectures were still used to deliver content. The students wrote the National Board Medicine Examination and the TBL examination scores were significantly higher than for those students involved in the lecturing-only mode. It was again thought that the reinforcement of content with TBL could be a contributing factor, but it also emerged that peer pressure influenced the students’ advance preparation.

In contrast with the reported studies, Conway, Johnson and Ripley (2010) and Grady (2011) did similar studies that showed no difference in student academic performance before or after TBL. Grady’s (2011) study compared lectures combined with workshops with TBL with an unknown number of pharmotherapeutic students. The assessment was an examination with the aim to compare students’ academic performance before and after implementation of TBL.

The study of Conway et al. (2010) used lecturing as a strategy, which was then changed to self-directed learning and case discussions. This was followed by six sessions of TBL, all used over the course of a cardiovascular module with an unknown number of students. The results of the multiple-choice questions examination showed no significant difference in scores before and after TBL implementation. Not all GRAT were graded for the TBL and it was reported that students were opposed to the advance preparation.

2.7.2 Student responses

Different student reactions were measured in all of the above-mentioned studies, except for the studies by Grady (2011) and Koles et al. (2010).

Jafari (2014) and Persky and Pollack (2011) used self-reported questionnaires to evaluate the students' satisfaction with teaching and learning with TBL. Students from Jafari's study (2014) were 80% satisfied with TBL teaching and the students from Persky and Pollack's study (2011) were 70% satisfied with what they learnt because of the TBL format.

Students in the sample group from Letassy et al. (2008) evaluated the course positively, but rated lecturing higher in 2003 than the TBL rating in 2006. They did, however, accept the change to TBL in the course.

Students also found TBL enjoyable and appreciated the improved participation in class and more engagement with their peers and lecturer when using TBL (Levine et al. 2004; Conway et al. 2010).

It seems clear that most studies comparing TBL with lecturing in terms of academic performance and student reactions indicate TBL as a promising educational strategy (Levine et al. 2004), as it enhances active learning versus passive learning from lectures. Student interaction and student-lecturer interaction seem contributing factors to active learning and teaching classes (Parmelee, 2008).

2.8 TEACHING AND LEARNING ANATOMY

Anatomy is the science of the structure of the human body and how the structures are related to one another (Tortora & Derrickson, 2011; Louw et al. 2009). Pandey and Zimitat (2007) described anatomy as a discipline with its own language to describe the internal organization of various structures and their relationships with other structures of the body. Anatomy may well be considered as the most significant core and foundational component in health science programmes (McLachlan & Patten, 2006; Haase, 2000; O'Byrne, Patry & Carnegie, 2008). Fasel, Morel and Gailloud (2005) even state that gross anatomy was once a "royal discipline".

The importance of accurate knowledge of anatomy is to ensure safe clinical practice. Patients expect that health care professionals have adequate basic knowledge in the foundations such as anatomy. The decline in anatomy knowledge is given as a reason for increasing medical errors which leads to increases in medico-legal litigation. Major litigation made educationalists acknowledge the lack of anatomical knowledge in younger generations of doctors (Older, 2004; Bergman et al. 2011; Xu, 2008; Raftery, 2006).

Traditionally, anatomy was taught by human cadaver dissection with personalized tutorials and didactic lectures (Older, 2004; Raftery, 2006). Old school and modern anatomists and medical students recognize that human cadaver dissection is the most powerful tool in teaching anatomy. It is a fit-for-purpose method to teach background information for clinical discussions, appreciation for three-dimensional viewing and to promote teamwork (Patel & Moxham, 2008; Kerby et al. 2011). According to Moxham and Moxham (2007) medical students prefer that anatomy is taught practically with dissections rather than theoretically.

Worldwide universities are changing and adapting due to reigning economic conditions. As anatomy departments are very expensive to run in a university, finances and costs are increasingly problematic. More students enrol but less time and money are available for teaching with a reduced number of anatomists (Lincacre, 2005; van Engelshoven & Wilmink, 2001; O'Byrne et al. 2008). As a result, content-packed curricula are presented with fewer lectures, more peer learning, tutorials and computer resources (Pandey & Zimitat, 2007; O'Byrne et al. 2008; Older, 2004). One major change was the scaling down of human cadaver dissections. Human cadavers are very costly to prepare for dissection and it has become almost unavailable due to ethical and moral objections (Parker, 2002). The use of pro-sections was advised for teaching purposes (Pandey & Zimitat, 2007; Older, 2004).

Anatomy teaching in medical education has always been the subject of much debate. In response to this debate Rizzolo, Stewart, O'Brien, Haims, Rando, Abrahams, Dunne, Wang and Aden (2006) designed a set of principles for an anatomy course. The authors set themselves the challenge of teaching more anatomy content in less time. Their research led to the following principles:

- Multiple formats should be used for presenting anatomy, thus dissection needs not be the only tool for teaching
- Students should be driven to learn by common clinical cases

- The clinical cases should be problem-based, because students prefer to practice and self-assess
- Medicine is practice in teams and if the clinical cases are investigated by teams of students, the course should promote working in groups
- Students should be taught to assess their own abilities and a safe environment must be created to discuss their assessments unafraid.

At the same time Pandey and Zimitat (2007) explored how students approach the learning of anatomy. The findings showed that the students employed both surface and deep approaches to learning. Surface learning such as memorization is used to recite facts and information in response to questions. Deep learning is associated with the understanding of facts and how it relates to the bigger picture. An important implication is that curricula are designed so that students may clearly see understanding content as an important goal of the curriculum (McLachlan & Patten, 2006; Scott, 1993; Smith et al. 2013).

Curriculum reform in anatomy is motivated by the shortcomings of the traditional curriculum and not just for the sake of change (Raftery, 2006). Teaching of medical anatomy however, is changing, and medical schools worldwide are moving to more integrated courses where anatomy and clinical skills are taught simultaneously.

Referring to an earlier remark by Pandey and Zimitat (2007) that anatomy is a language on its own, it must be used in the correct context, be relevant and applied correctly like any new language. This may be the biggest problem with current teaching methods, namely, that fundamental anatomy knowledge is taught, but not much application of such knowledge (Gregory, Lachman, Camp, Chen & Pawlina, 2009). Standring (2009) adds that factual anatomical information can be accessed by a click of a mouse, but this will not lead to adequate applied knowledge. A teaching method thus needs to emphasize and reinforce anatomical knowledge, while the relevance of this knowledge has to be clear in its implementation (Johnston, 2010; Johnston & McAllister, 2008). Teaching anatomy thus has to be clinically orientated and clinical cases should be used for the application of anatomical knowledge (Scott, 1993; Louw et al. 2009).

In an effort to overcome some of the challenges related to the teaching of anatomy many universities implemented PBL as a teaching-learning strategy. PBL features the presentation of a clinical problem to students without the necessary information to solve the problem. It comprises of individual and small group work with guidance and feedback from a tutor (Beers, 2005).

However, the assessment of PBL as a teaching strategy over time raised concern regarding the level of anatomical knowledge that students exhibited. Anatomists started seeing anatomy as diminished, fragmented and the regions of the human body that did not fit into PBL tutorials tended to be ignored (Louw et al. 2009). Contrary to such perceptions, research by Prince, van Mameren, Hylkema, Drukker, Scherpbier and van der Vleuten (2003) indicated that PBL did not result in a lower level of anatomy knowledge than what was required with more traditional approaches. This research was repeated in 2005 and showed that students' anatomy knowledge was insufficient, but applied equally to PBL and non-PBL students (Prince, Scherpbier, van Mameren, Drukker & van der Vleuten, 2005). The researchers concluded that the problem could rather be that the level, content and depth for anatomy curricula were not sufficiently identified.

Xu (2008) complained that medical students at the time found themselves being ridiculed, if not scolded, for their lack of anatomy knowledge. He blamed self-directed PBL for this situation, because independence in learning also creates different learning outcomes in anatomy – some students will develop great gains in anatomy knowledge while others, will have unacceptable levels of such knowledge.

Traditional anatomy teaching is often regarded as too structured and passive, but in the same vein, PBL is providing too little direction for achieving anatomy knowledge and applications (Singh & Sido, 2008).

2.9 TEACHING ANATOMY WITH TBL COMPARED TO THE LECTURE METHOD

Traditionally, anatomy was taught as a lecture-based course, but TBL became an attractive strategy that required students to learn anatomical facts that they then applied to clinical scenarios by group problem-solving techniques (Vason & DeFouw, 2004; Nieder et al. 2005).

Nieder et al. (2005) taught a gross anatomy course using multiple teaching modalities, but mostly traditional 'live' lectures. However, the lecturers experienced various problems such as poor student attendance and different degrees of student preparation. The question thus arose whether TBL would not be more meaningful as a teaching tool, as it forces students to keep up with the course material. Previous studies found that students' academic performance improved with TBL compared with the results of previous years (Zgheib et al. 2010; Zingone et al. 2010).

The researchers, Nieder et al. 2005, set out to implement TBL instead of using lectures with the intent to explore students' experience with TBL, to generate data on student academic performance and on the experiences of academic staff with TBL.

A pure TBL process as advocated by Michaelsen and Sweet (2008) was implemented with 97 first-year medical students randomly selected into 18 teams of five to six students per team. Two students dropped out, which brought the total of participating students to 95. Three lecturers were involved with the implementation.

In this research study (Nieder et al. 2005) particular attention was paid to the grading system that always concerns students (Michaelsen & Sweet, 2008). Three major examinations were written, which accounted for 75% of the course grade and the students had to score 70% on average for these examinations. The TBL activities contributed 25% of the course grade and the students had to score 70% average on the overall course grade, which included the TBL scores.

Students were asked for their input with regard to a fair weighting system for Individual Readiness Assurance Tests (IRAT), Group Readiness Assurance Tests (GRAT), Group Application Practice (GAP) and peer evaluation. Their recommendations were that 20% should be allocated for individual performance, 50% for group performance and 30% for peer evaluation. Each student's TBL grade was calculated using this formula. The results from student evaluation of TBL showed that most students thought that the TBL grade comprising 25% of the course grade was appropriate.

Peer evaluation caused the most controversy with the students. They were very reluctant to score their peers for grading purposes. Several students admitted that their teams fixed the scores. This particular study required the students to complete two forms for each team member three times during the course. The first form was a component of the TBL grade and the students had to write a justification for the score given. The second form was a formative evaluation to rate their peers in cooperative learning skills, self-directed learning and interpersonal skills. These forms were to be seen by the students only and the faculty did not have access to this information. The researchers predicted that in future years an alternative method for peer evaluation will have to be found (Nieder et al. 2005).

While evaluating TBL 83% students agreed or strongly agreed that TBL helped them with their learning. TBL sessions were found to be more helpful than traditional lectures by a considerable margin. All three lecturers wanted to continue with TBL, because of the high engagement of students and the value of the advance preparation the students did (Nieder et al. 2005).

Evaluation of academic performance showed no significant difference between the average examination scores over four years, but there were fewer failures with TBL. Thus, a major benefit of TBL is that it is beneficial for academic weaker students. The researchers offered a possible reason that the IRAT forced students to stay on top of the anatomy content. A strong correlation consisted between a student's IRAT and examination scores, making the IRAT a good predictor for students' performances on major examinations (Nieder et al. 2005).

At about the same time, Vasan and DeFouw (2005) reported to have experienced the same problems as Nieder et al. (2005) and decided to replace anatomy lectures with TBL in a gross anatomy course. They implemented a modified TBL process with 175 students. The modifications included the exclusion of phase three by adapting phase two to include patient-based cases. Not all the IRATs and GRATs were graded to be added to the course grades. Peer evaluations were done but did not contribute to the course grades. It was used for proactive counselling for students who did not do adequate advance preparation.

Three MCQs examinations were written. The questions contained 90% clinical vignettes that tested student knowledge, comprehension and problem-solving skills. The class average for the first examination scores was 77% that was approximately 5% higher than the first examination scores from the previous years, which was also a clinically orientated MCQs examination. An explanation for this increase in marks is probably because the students must prepare constantly to do the assignments with TBL, which excludes cramming before examinations. Team discussions and shared resources also enhance academic performances.

Semi-structured interviews, observations and student self-reporting provided data on student engagement on cognitive basis and behavior. The findings showed that the student engagement was extremely satisfying, but opinions on student to student and student to faculty interaction varied.

The conclusion of this study showed TBL as effective and efficient and it appealed to both the students and faculty. An encouraging observation was about students who did not attend class, with TBL the class attendance was 100% (Vasan and DeFouw, 2005).

Vasan and DeFouw (2005) summarized the lessons that they learnt from their first TBL pilot study. They found TBL was an excellent substitute for lectures. The construction of appropriate advance preparation material was critical to the success of TBL. To do the RATs was essential, because this was where feedback and considerable teaching and learning occurred. Deeper learning was experienced by the students and they were excited to come to class.

The studies from Nieder et al. (2005) and Vasan and DeFouw (2005), although both conducted in a similar anatomy course, showed different results with regard to student academic performance, but similar findings with student reactions to TBL. However, student attendance in both studies significantly increased. Different methodologies were used; while Nieder et al. (2005) employed a pure TBL process, Vasan and DeFouw (2005) used a modified TBL model. In future it will be interesting to research the implementation of TBL in a similar anatomy course using the same methodology.

Following on the study from 2004, Vasan, DeFouw and Compton (2009) conducted research at the same university with students in the same anatomy course. The aim of the study was to develop a valid and reliable instrument to measure student perceptions of TBL. Faculty and student focus groups developed a formal questionnaire to gather student feedback on their experiences with TBL. The questions looked at the students' preparation for group discussions, the usefulness of assignments for acquiring knowledge, the importance of group discussions, attitudes about team behavior and mutual respect during team discussions.

In addition to the questions on perceptions of TBL, the students were asked to provide the grade they anticipated receiving in the coming final examinations.

The questionnaires were administrated to two cohorts of students, academic years 2006 – 2007 and 2007 – 2008. Three hundred and seventeen (90%) students responded to the questions on their perceptions of TBL and teamwork and three hundred and fifteen students responded to the question regarding their expected grade. The findings on perceptions of TBL showed that honors (> 90%) students rated TBL higher than pass (70 – 80%) students and higher than fail (< 70%) students. High-performing students had significantly greater perceptions of TBL than low-achieving students although all students had positive perceptions of TBL. A possible interpretation can be that high-achieving students overcome negative perceptions on active learning quicker and adapted more readily to the benefits of TBL.

The results from the question on the students' ability for self-assessment based on their performances were informative. Three hundred and eleven students who expected to pass the course performed better than their predictions and only the failing students made inaccurate predictions about their grade outcomes. With TBL, students received frequent feedback from the lecturers and their peers to identify knowledge gaps, which they then addressed and thus improved their ability to self-assess and predict their grade outcomes.

2.10 SUMMARY

It seems clear from relevant literature on different teaching strategies, that TBL is a teaching-learning strategy that employs active learning and is increasingly used in medical education.

TBL is a student-centered teaching strategy, which promotes the application of knowledge and presents opportunities for the students to solve clinical problems by using course content. It thus seems a viable option to promote in the teaching of anatomy where the application of theoretical knowledge is a key concern.

Traditionally, however, anatomy was taught via conventional lectures which, according to relevant literature, promote student inactivity, none or little student engagement and surface learning, but are efficient in terms of time and cost. The results from reported studies comparing lecturing with active learning strategies showed that the academic performances of students seem to improve as the use of active learning strategies increase. Students also indicate higher levels of satisfaction when actively involved in their learning instead of listening passively to lectures. These findings support the view that lecturing may not be the most effective as a teaching strategy, but that it does have a place in teaching certain concepts in anatomy.

What relevant literature also shows is that the results of research on academic performance, when comparing TBL with other active learning activities are inconsistent.

However, the comparisons between TBL and lecturing show significant differences in the academic performance of students in favor of TBL. The reasons given to explain such findings include better student engagement, teamwork with better communication and reinforcement with repetition. Students reportedly also find TBL sessions enjoyable and, importantly, it appears that academically weaker students benefit from being exposed to TBL.

When TBL and lecturing is compared for anatomy, the results show that TBL seems to be a possible substitute for lecturing, but that the kind and structure of the course material is an important variable.

Literature reporting relevant studies on the suitability of teaching strategies also reveal that TBL relates positively to enhancing student learning, as, it is an active, student-centered strategy. In most reported studies for anatomy, TBL seems to be effective in enhancing deep learning and the opportunity to practice clinical applications. While most results of the research showed positive gains in student engagement, the academic performance of students varied considerably. One finding related to student academic performance, however, was consistent in that low-achieving students benefit more by using TBL. The need for further research for evidence on the effectiveness of TBL seems crucial for the development of TBL in university teaching and learning.

Another need for further research would be the training of academic staff to overcome resistance, the fear of losing anatomy content and potential increases in workload to structure advance preparation assignments. At the same time, further research is also needed on why lecturing remains to be an attractive alternative in spite of other more effective teaching strategies.

The next chapter of the study will describe in more detail the research design and methodology that was utilized to investigate the research questions as posed.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The primary aim of this study was to determine the relative influence of two different teaching strategies, team-based learning (TBL) and lecturing, on the academic performance of a group of undergraduate radiography students in anatomy studies.

The secondary aims of this study were to explore the first-year radiography students' perceptions of their engagement with TBL and the potential usefulness of TBL as a future teaching strategy and whether academically weaker students identified by their examination grades might benefit more from the use of TBL.

To achieve these aims, a quasi-experimental research design was selected as the most appropriate design, discussed in par. 3.3.1, to generate quantitative data on comparing two teaching strategies for one group of anatomy students. Data were generated by comparing the academic performance of students with regard to two anatomy learning objectives, as students were subjected to lecturing for one group and TBL for another group on the basis of a crossover quasi-experimental design. Pre- and post-test scores were used as an applicable measurement.

In addition, quantitative data were generated to explore radiography students' perceptions of their engagement with TBL as well as their views on the usefulness of TBL as a future teaching strategy. Data on beliefs and attitudes do not naturally appear in numeric form, but can be generated by designing instruments that will measure responses to questions and statements quantitatively in order to make statistical analyses possible (Muijs, 2011).

To establish whether academically weaker students might have benefitted more from the use of TBL, quantitative data were obtained by calculating the average score of the three tests/examinations previously written by all students during the year as part of their formal assessment and comparing these with the students' post-test results.

The reason for collecting three sets of data was to obtain a more comprehensive overview of the research problem and to work towards a possible solution to the research problem. Findings from the experimental and student experience data were compared to similar reported studies to determine whether the results of this study supported or rejected the trends in existing literature.

A more detailed description of this study's methodology will be discussed in the following sections.

3.2 RESEARCH APPROACH

The key element of all research is that researchers are looking to explain something (Muijs, 2011). Grove, Burns and Gray (2013) define it more elegantly as an investigation to validate existing knowledge and to generate new knowledge. In order to do this Mouton (2001) declares that a researcher must have a plan or blueprint of how he/she intends to conduct the research. The plan for this research study will be discussed next.

This study made use of quantitative data generated within a positivist knowledge paradigm. A paradigm or a philosophical worldview refers to how the researcher in general views the world in relation to his/her research. Positivists take the view that research uncovers an existing truth or reality by measuring numerical data objectively and then analyze this data statistically (Parahoo, 1997; Muijs, 2011). This view is also known as traditional, scientific or empirical research because a researcher begins with a theory and then collects data to either support or reject the theory (Creswell, 2009). Positivists believe in the notion of cause-and-effect relationships and look for explanations in empirical data, particularly to logic for the interpretation of data (Grove et al. 2013; Parahoo, 1997). Researchers must eliminate bias by being as detached as much as possible and by using methods that will minimize their involvement (DePoy & Gitlin, 1998). Positivism is the philosophical foundation for using quantitative methods in research and mainly relates to explaining or predicting the relationship between variables in a research study (Creswell, 2009). In this study, however, no hypotheses were formulated and there was no intention to prove relationships among variables or to generalize. What made the study positivist in nature is the fact that students' performance results were compared in terms of the type of teaching intervention they were exposed to, which could be used for making inferences about which strategy is the more effective.

Creswell (2009) reminds us that the use of quantitative data implies structured, predetermined methodology to quantify how much change, if any, occurs between the cause and effect to explain a certain phenomenon. Other researchers proposed strict control of the process of measuring variables to enhance the validity and quality of data and, in turn, relies on logical reasoning to obtain results (Neutens, 2014; Leedy & Ormrod, 2010).

One of the benefits of using quantitative data is high reliability because the research can be repeated and replicated (Kumar, 2011). Usually, quantitative research collects data to explain questions that can be answered immediately, for example, 'How many students passed test one?', but questions on beliefs and attitudes require another quantitative approach. Data on beliefs and attitudes do not naturally appear in numeric form, but can be generated by designing instruments that will measure responses to questions and statements quantitatively in order to make statistical analyses possible (Muijs, 2011).

A possible challenge to quantitative data is to explore a problem in depth. Quantitative data can provide information in terms of breadth, but to explore a concept in depth, quantitative methods can sometimes be too superficial. When studying human behavior, for instance, quantitative methods are limited to measuring behaviors that are observable only (Parahoo, 1997).

In summary it can be said that quantitative methods are best for investigating possible cause-and-effect relationships while qualitative methods are more suited to looking at the meaning of particular events.

3.3 STUDY DESIGN

3.3.1 Quasi-experiment

A cross-over comparative quasi-experimental design was used for this study. In all types of experimental designs there is an assumption of a cause-and-effect relationship (Kumar, 2011). True experimental research has three components including randomization, comparison groups and controlled manipulation of the treatment/intervention (Grove et al. 2013). Gray (2009) defines true experimental research as when participants in a research study are randomly assigned to either an experimental or a control group. An intervention is done with the experimental group, but not with the control group. The results of the two groups are compared to investigate different aspects of the research problem.

Quasi-experimental designs search for the same causality in certain situations, but complete control of a study design is not always possible. Quasi-experiments try to control as many threats to validity as possible, but usually at least one of the above-mentioned three components of a true experiment is lacking (Grove et al. 2013). Quasi-experiments do not control all extraneous variables, so alternative explanations for results obtained cannot be completely ruled out.

Interventions of quasi-experiments are done in natural settings such as classrooms, also referred to as ‘field work’ (Denscombe, 2008). Quasi-experimental research uses existing groups, also referred to as ‘field experiments’ (Hofstee, 2006). Neuman (2000) states that in quasi-experiments, as in true experiments, the researcher tests for causal relationships in different situations. Tashakkori and Teddlie (2010) suggest that quasi-experimental research is similar to true experiments with regard to intervention and measuring outcomes. Ethical and practical reasons sometimes prevent true experiments to be carried out in education (Parahoo, 1997), but using quasi-experimental designs will be a ‘second-best option’ to determine causality (Muijs, 2011).

One of the biggest differences between true experiments and quasi-experimental designs is randomization. Randomization is the process of assigning participants to either the experimental or control group and the participants have a 50/50 chance of being assigned to either group. However, in quasi-experimental designs, the participants are in an existing group and this is referred to as convenience sampling, purely on the basis that they are conveniently available (Gray, 2009). Convenience sampling presents a problem that the researcher cannot be certain of how much the sample represents a bigger sample of the population, but it can be advantageous as it limits researcher bias in selecting participants (Creswell, 2009).

Experimental research means that the experimental group will receive a treatment and the control group also. Although denying treatment to a control group, especially in educational settings, can be regarded as unethical and may be unacceptable to some individuals in the control group (Kumar, 2011). To overcome this particular problem and when two interventions are used, a cross-over design can be used. Cross-over designs are when the control group for the first intervention of the experiment becomes the experimental group for the second intervention and vice versa (Neuman, 2000).

Advantages of experimental research are the control and rigor when gathering evidence for causality; it is cost-effective and less time-consuming. Challenges include that some questions cannot be answered using experiments and external validity, because many experiments rely on small non-random samples of participants (Neuman, 2000).

Validity is described as the accuracy and appropriateness of the research model and can be divided into internal and external validity (Kumar, 2011). Internal validity is the probability that factors associated with the process of experiments are responsible for the changes in data, for example in this study, the results of the pre- and post-tests. External validity is the extent to which the experiment allows generalization of the findings to a bigger audience (Sarantakos, 2007).

Strategies to ensure the internal validity include the amount of control, double-blind experiments and unobtrusive measurements. In this quasi-experiment, the control, double-blindness and unobtrusive measures lowered the internal validity, because there was control of the environment, but not as much as for a true experiment. Only the participants were blinded as to which intervention they will be getting, but the researcher was not blinded and the participants knew they were being observed during the experiment.

External validity can be enhanced by a real-life setting that is not artificial, a representative sample and the replication in a different context. This study had a real-life setting, as it normally occurs in everyday routine, but the sample was small and could possibly not be representative of a bigger group. This study has not been replicated in a different context, which would threaten the external validity (Leedy & Ormrod, 2010). Usually quasi-experiments have a high external validity and a low internal validity (Neuman, 2000).

3.3.2 Participants

This study was conducted during 2013 in the programme for the National Diploma in Radiography at the Cape Peninsula University of Technology. A convenience sample of the existing group of forty first-year students' first attempt at anatomy was used as the study population.

Within the quasi-experiment the individual students were randomized according to an alphabetical class list into two groups e.g. individual 1 to group1, individual 2 to group 2 until every student was divided into group 1 or 2. Group 1consisted of 22 students and group 2 had 18 students. No selection criteria such as age, gender or academic performance were used and no systemic bias was assigned.

A cross-over design was used, but will be discussed under the section describing the data collection phases.

Within the TBL intervention groups of students were alphabetically assigned into five teams, named A to E, of eight students each. The researcher, as the lecturer responsible for facilitating anatomy teaching, also participated.

3.3.3 Data collection instruments

Quantitative data for this study were generated with pre- and post-tests to measure the change in student academic performance after the implementation of two different teaching strategies used for teaching two different anatomy topics.

Feedback questionnaires were completed by the participants to explore their perceptions on their engagement with TBL and how useful TBL might be to them as a future teaching strategy. The results from the questionnaires were converted into numerical data sets and were statistically analyzed.

Pre- and post-tests

According to Kumar (2011) the pre-and post-test design can be defined as two sets of data collections from the same study participants to determine the change in the outcomes between two points in time. This design is the most appropriate design for measuring the effectiveness of an intervention. Pietersen and Maree (2007) state that pre- and post-tests are classic examples of a data collection instrument in an experimental (also quasi-experimental) setting. The results of the pre- and post-testing provide numerical data for statistical data to determine which intervention produced better results.

The main advantage of testing as a data collection instrument is its ability to measure change in a given situation, but on the other hand it measures total change and the researcher cannot be certain that no other factors were responsible for some of the change. The limitations of the tests include expensiveness, difficult implementation and it can be time-consuming.

The validity of research instruments that generate quantitative data refers to whether the findings of a study are in accordance with what the researcher wanted to find out (Leedy & Ormrod, 2010). For this research, the pre- and post-testing was the quantitative measuring instrument. The testing was done to measure the academic performance as set out in the primary research aim. The pre-and post-tests will provide results to measure the student academic performance before and after the interventions. It can be said that pre-and post-test results are valid research instruments for measuring increase or decrease in student academic performance.

A research instrument is reliable if "it has the ability to produce consistent measurements each time it is used" (Kumar, 2011). The pre- and post-tests, when used under similar conditions, will obtain similar results, whether there was an increase or a decrease in academic performance after an intervention, which will make testing a reliable research instrument.

Student questionnaires

Gray (2009) defines a questionnaire as a research tool where participants of a study are asked to respond to the same set of questions arranged in a certain order. The information gathered from questionnaires falls into two categories: factual information such as age, gender or marital status and secondary information on participants' opinions, views or beliefs (Denscombe, 2008).

Questionnaires are quantitative in nature when they are constructed in advance, standardized and structured so that participants can choose from a list of responses offered by the researcher (Parahoo, 1997). A questionnaire can also contain open-ended and/or closed questions. Open-ended questions allow respondents to answer questions in their own words, whereas closed questions let the respondents choose between answering options provided by the researcher. A rating scale such as the Likert-type response scale is attached to closed questions (Muijs, 2011). This scale was created by Rensis Likert in 1932 and is still in use today. According to Neutens (2014) it uses numerical values attached to a specific response such as 1 = 'strongly agree', 2 = 'agree', 3 = 'disagree' or 4 = 'strongly disagree'. Such options lead to one of the strengths of structured questioning: that numerical values can be statistically analyzed to describe and compare responses (DePoy & Gitlin, 1998). A disadvantage of structured closed questions is that they provide less scope for the respondent to express her/his own opinions or feelings. Open-ended questions require respondents to write their responses in their own words, giving the respondents a sense of control and adding different dimensions to respondents' views. The disadvantages of open-ended questions are that people are not always willing or confident to write and this type of data can be difficult to analyze or to interpret (Hofstee, 2006).

As a method to generate data, the advantage of questionnaires is that a large number of people can be reached and that it is not too expensive in terms of time or money (Leedy & Ormrod, 2010).

The main disadvantage of the use of questionnaires is normally a low response rate which will influence the amount of data generated and maybe lead to a position where no significant statistical results can be calculated (Leedy & Ormrod, 2010). Pietersen and Maree (2007), however, suggest a group collection if possible to overcome this problem. A group collection is when the researcher is present while a whole group of respondents complete their individual questionnaires for an optimal response rate.

In this study, the feedback questionnaire (see Addendum F) was adapted from existing questionnaires that were used to evaluate student engagement with TBL and the usefulness of TBL. It elicited information about participants' opinions, views, beliefs and preferences about TBL. The questionnaire for this study contained six questions that could be rated according to a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Numerical values were assigned to the questions in order to generate quantitative data for analytical purposes. An opportunity was created for participants' own opinions in terms of comments, positive or negative. The participants' comments were thematically analyzed to add depth to the results of the quantitative data analysis with regard to students' feedback and engagement with TBL.

The visual appearance, the type of questions and the sequence of the questions were in line with the information the researcher wanted. The questionnaires were completed anonymously and voluntary. The researcher attached a note of thanks for completing the questionnaires.

3.4 PHASES OF DATA COLLECTION

The primary aim of this study was to determine the relative influence of two independent variables, TBL and lecturing, on the dependent variable, academic performance of two groups of undergraduate radiography students with regard to two learning outcomes, namely, the anatomy of the wrist and the elbow respectively.

The data collection was done on the 6th September 2012.

One week prior to the quasi-experiment, the researcher met with the forty participating students to explain the purpose and the implementation process of the research as depicted in Figure 3.1. Any questions or concerns were answered and explained. The students did not do a 'dummy' run, which could have had an influence on the final outcome.

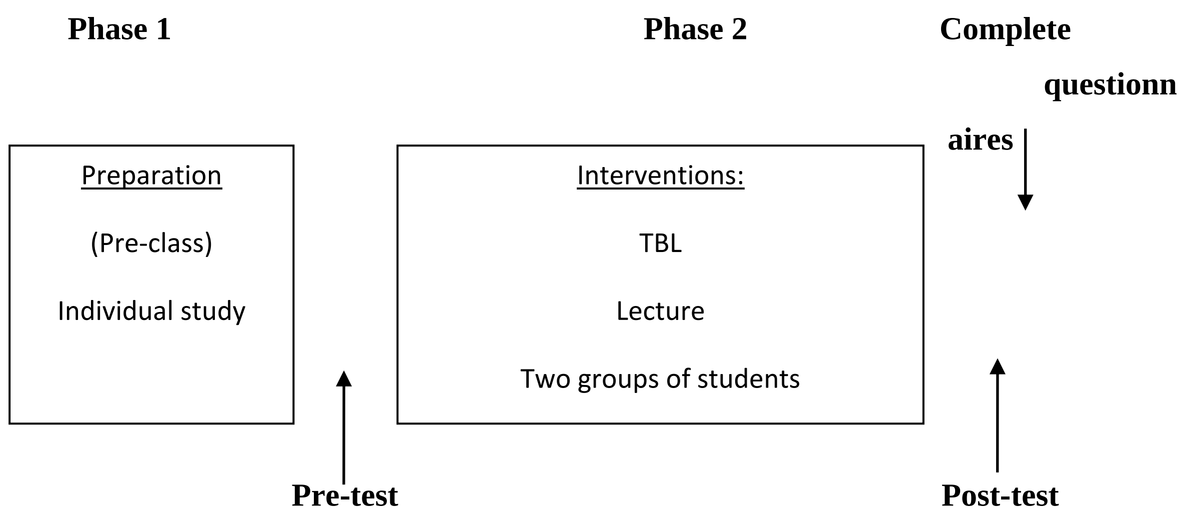

Figure 3.1: Phases of instructional activity sequence. (Adapted from Tan, Kandiah, Chan, Umapathi, Lee & Tan, 2011)

Phase 1, as depicted in Figure 3.1, was set in operation by providing the students with reading assignments (see Addendum C) on the anatomy of the wrist and the elbow.

These two learning outcomes were randomly chosen from the first-year anatomy syllabus. The reading assignments were prepared by the researcher from the prescribed anatomy text book. The students were asked to individually study the notes in preparation for phase 2 of the instructional activity sequence in Figure 3.1.

One week later, phase 2 (see Figure 3.1) was conducted in a lecture room with the researcher as facilitator and the forty participating students.

To assess the student academic performance as the primary outcome, two closed-book tests were written by every student. A baseline pre-test was administered prior to the start of phase 2 and a post-test was done at the end of phase 2.

The pre-test (see Addendum D) consisted of 20 multiple choice questions on the anatomy of the wrist and 20 multiple choice questions on the anatomy of the elbow. To answer the questions the students needed recall of the anatomy of the wrist and the elbow respectively as summarized in the pre-class study notes. The maximum score was 20 marks for each test and 20 minutes were allocated to write each test.

The post-test (see Addendum D) was the same in content, structure, maximum score and time allocation. The pre- and post-tests scores represented the quantitative data to establish the primary outcome of this study.

After the pre-test, phase 2 (see Figure 3.1) that involves the intervention processes with TBL and the lecture method were conducted. Up to this point, the students were unaware which topic (anatomy of the wrist or anatomy of the elbow) would be used for the TBL intervention of phase 2. The forty individual students were now randomized according to an alphabetical class list into 2 groups with Group 1 consisting of 22 students and Group 2 had 18 students. A cross-over design was used meaning that the control group for the first intervention of the experiment will become the experimental group for the second intervention and vice versa (Neuman, 2000). The group allocation is depicted in Table 3.1.

Table 3.1: Group allocation in the cross-over design

Anatomy of the wrist:

Intervention	Intervention
Team-based learning Group 1 – Experimental group	The lecture method Group 2 – Control group

Anatomy of the elbow:

Intervention	Intervention
Team-based learning Group 2 – Experimental group	The lecture method Group 1 – Control group

According to Table 3.1, Group 1 as the experimental group had a TBL intervention, but Group 2 as a control group a lecture method intervention with regard to the anatomy of the wrist. After cross-over, Group 2 as an experimental group had a TBL intervention, and Group 1 as a control group a lecture method intervention with regard to the anatomy of the elbow. In summary, each group has a lecture method and a TBL experience on either the anatomy of the wrist or the elbow.

During phase 2, the lecture method interventions were done by presenting information on the anatomy of the wrist or the elbow (depending on the group) in the traditional way of the lecturer standing in front of the class, presenting a 20 minute Power Point® presentation. The students were the passive audience listening to the presentation. At the end of the lecture, there was an opportunity for the students to ask questions with regard to any uncertainties they may have had on the content of the lecture.

The TBL intervention during phase 2 was a modified TBL method with a combination of the three phases of pure TBL application.

Phase 2

Step 1 **IRAT** Individual readiness assurance test	Step 2 **GRAT** Group readiness assurance test	Step 3 **Tutor clarification**

Figure 3.2: Different steps in the modified TBL method

The group assigned to the TBL intervention, started off with step 1, the individual readiness assurance test – IRAT, as illustrated in Figure 3.2. The IRAT was undertaken by each individual student. The IRAT (see Addendum E) was based on clinical scenarios with appropriate accompanying x-ray images with three plausible choices to answer the questions using a multiple choice question format. The questions required the students to recall facts studied during phase 1 and to apply this knowledge in order to answer the questions correctly. Three case studies were used for the application of the anatomy of the wrist and four case studies for the elbow anatomy. These tests were handed in and marked.

After the IRAT, the students were randomly assigned to 8 students per teams A to E. These groups did the second step, group readiness assurance test – GRAT (see Addendum E) as illustrated in Figure 3.1. During GRAT, each team did the same clinical case studies as in the

IRAT. The different teams had 20 minutes for group discussion and to formulate a team answer by consensus. The teams were asked to state their consensus answer and to justify their answers. The facilitator provided the correct answers afterwards. The corrected IRATs were handed back to the individual students for them to compare their answers to the correct GRAT answers. During the last step in Figure 3.1, the facilitator clarified any misconceptions that were recognized during the group discussions or the marking of the IRATs.

The students then wrote the post-test and were asked to complete a questionnaire (see Addendum F) as shown as the last steps in Figure 3.1. The questionnaire dealt with the students' opinions about their engagement with TBL and whether they thought TBL was a useful teaching tool. The data from the questionnaire answers were analyzed and the results will be reported in the next chapter.

3.5 DATA ANALYSIS

Although collecting data is an important part of the research process, the raw data in itself will not answer the research questions. The data must be organized and interpreted according to systematic and mathematical procedures known as statistical analysis which will allow the researcher to make sense of the data in order to understand it (DePoy & Gitlin, 1998; Parahoo, 1997).

The students in this study were numerically coded and their pre- and post-test scores for each intervention were recorded. The mean of the last three tests/examinations was calculated and recorded for each student. The completed questionnaires were coded according to the topic, wrist or elbow anatomy, and numbered.

This study had three sets of quantitative data, the pre- and post-test data and data from the questionnaires and the data analysis consisted of identifying the means, standard deviations and the range of scores of variables. The data were presented in table format and graphs.

The primary aim of this study was to measure the influence of two different teaching methods, TBL and the lecture method, on student academic performance. The measurement tool to measure this was a pre- and post-testing to obtain numerical values for the differences in the scores for the two tests.

A parametric *t*-test was preformed to compare the mean percentage of two groups of students with regard to academic performance where one group's intervention was TBL and the other group who was lectured. A *t*-test is a basic statistical procedure used to compare the mean percentage of two groups on one variable, namely, the student academic performance in this particular study. This comparison determined the impact of the interventions, either TBL or the lecture method, on student academic performance.

One of the secondary aims was to explore the students' perceptions of their engagement with TBL and the usefulness of TBL as a future teaching strategy. This information was obtained from the questionnaires that were completed by each student individually. The findings were expressed as percentages. The students' comments were reported under different themes with verbatim quotes.

The second secondary aim was to investigate the interaction between TBL, the lecture method and examination/test grades. An analysis of variance (ANOVA) was done to plot the mean percentage of the examination scores versus the post-test scores for both interventions TBL and lecturing. The purpose was to determine whether academically strong or weak students benefitted more, less or the same from TBL or lecturing.

Finally, Plowright (2011) stated that all data gathered are the result of an experiment done by the researcher. The researcher then structures the gathered information by systematically coding the information into data that can be organised to generate meaning to the research. This can be achieved by using both numbers and words.

3.6 ETHICAL CONSIDERATIONS

The participants were notified and informed concerning the reasons for the study as well as the conditions of participation and their rights regarding participation (Leedy & Ormrod, 2010). The participants were given the choice to participate in the study. Informed consent forms (see Addendum A) were signed, while anonymity was assured. Data will be used for the sole purpose of the research, remain confidential and kept locked in a safe place and will be destroyed after the data analysis had been completed.

Ethical clearance was granted by Stellenbosch University Human and Social Sciences Ethical Committee and the Research Committee at CPUT (see Addendum B).

3.7 CONCLUSION

This chapter has outlined the research methodology used in this study including the data collection instruments and the data collection phases.

The research objectives were linked to the use of quantitative research methods, including data generation through a quasi-experiment.

The analysis and interpretation of the collected data enabled the researcher to come to conclusions about implementing either TBL or lectures for teaching anatomy to first-year radiography students, which will be discussed in Chapter 4.

CHAPTER 4

FINDINGS

4.1 INTRODUCTION

The aims of this study were threefold:

1. To determine the relative influence of two different teaching strategies, TBL and lecturing, on the academic performance of undergraduate radiography students in anatomy studies.
2. To explore the first-year radiography students' perceptions of their engagement with TBL and the potential usefulness of TBL as a future teaching strategy.
3. To explore whether academically weaker students identified by their examination grades will benefit more from the use of TBL.

In this chapter, three different sets of generated quantitative data were analysed to present the findings using tables and graphs with a summary of the results.

4.2 FINDINGS

Forty (N=40) first-year National Diploma Radiography students at Cape Peninsula University of Technology during 2013 were used as a convenience sample. The students were randomised into Group 1(n = 22) and Group 2 (n = 18) according to an alphabetical class list.

4.2.1 Quantitative data generated from the pre- and post-tests

The pre- and post-tests result of the two learning outcomes, anatomy of the wrist and the elbow, were used to measure the students' academic performance after TBL and lecturing were used as interventions in a crossover design for the two groups of students.

4.2.1.1 Learning outcome: anatomy of the elbow

Table 4.1 shows the intervention as done for the learning outcome, anatomy of the elbow.

Table 4.1: Elbow anatomy for 2 groups and 2 interventions

Pre-test Elbow anatomy	**Lecture Intervention**	**TBL Intervention**	**Post-test Elbow anatomy**
Group 1 and 2	Group 1	Group 2	Group 1 and 2

The mean percentage change was used to reflect the change, if any, in the student academic performance. As the aim of the study was to compare TBL and lecturing, the mean percentages between the elbow anatomy for TBL and lecturing interventions are shown in Table 4.2.

Table 4.2: Elbow anatomy: TBL versus lecture

	Intervention	**n**	**Mean**	**Std Deviation**	**Std Error Mean**
Difference	**Lecture** Elbow anatomy Group 1	22	8.6364	13.10959	2.79497
	TBL Elbow anatomy Group 2	18	11.3889	17.13318	4.03833

The outcome for the anatomy of the elbow showed TBL on 11.4% mean change and lecturing on 8.6% mean change (see Table 4.2).

The mean % change (see Table 4.2) and the graph (see Figure 4.1) indicate that TBL might be a more effective teaching strategy than lecturing in terms of student academic performance on the relevant test.

Figure 4.1: Anatomy of the elbow: Mean % changes in pre-and post-test scores

However, according to the *p*-value (*p* = .548) as reflected in Table 4.3, there was no significant difference between TBL and lecturing interventions for the anatomy of the elbow.

Table 4.3: p-value for comparison of TBL and lecturing

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	**p-value**	t	df	p-value (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Difference	Equal Variances Assumed	.367	**.548**	-.576	38	.568	-2.75253	4.78106	-12.43127	6.92622
	Equal variances not assumed			-.560	31.362	.579	-2.75253	4.91121	-12.76432	7.25927

4.2.1.2 Learning outcome: anatomy of the wrist

Table 4.4 shows the interventions as done for the learning outcome, anatomy of the wrist.

Table 4.4: wrist anatomy for 2 groups and 2 interventions

Pre-test **Wrist anatomy**	**Lecture** **Intervention**	**TBL** **Intervention**	**Post-test** **Wrist anatomy**
Group 1 and 2	Group 2	Group 1	Group 1 and 2

The mean percentage change was used to reflect the change, if any, in the student academic performance. As the aim of the study was to compare TBL and lecturing, the mean percentages between the wrist anatomy TBL and lecture interventions are reflected in Table 4.5.

Table 4.5: Wrist anatomy: Lecture versus TBL

	Intervention	**n**	**Mean**	**Std Deviation**	**Std Error Mean**
Difference	**TBL** Wrist anatomy Group 1	22	6.5909	8.78125	1.87217
	Lecture Wrist anatomy Group 2	18	21.9444	15.82430	3.72982

The outcome for anatomy of the wrist showed TBL on 6.6% mean change and lecturing on 21.9% mean change (see Figure 4.2).

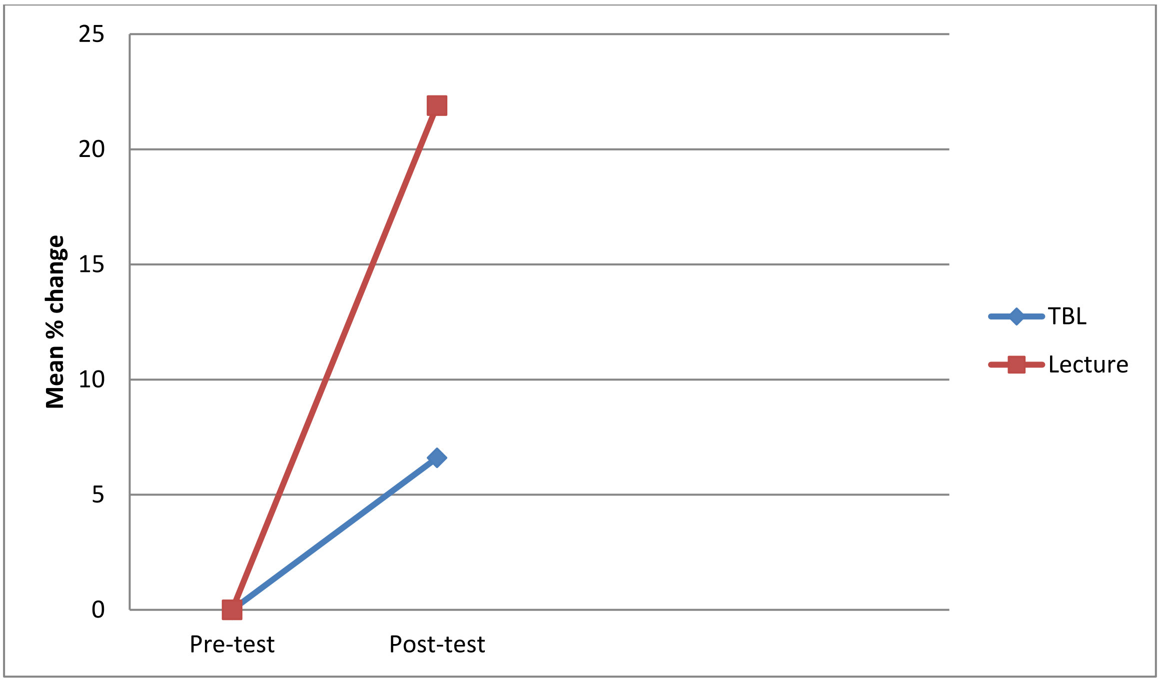

Figure 4.2: Anatomy of the wrist: Mean % changes in pre-and post-test scores

This graph indicated that lecturing might be a more effective teaching strategy than TBL in terms of student academic performance on the relevant test.

However, according to the *p*-value (*p* = .029) as shown in Table 4.6 there was a significant difference between TBL and lecturing interventions in favour of lecturing for anatomy of the wrist.

Table 4.6: p-value for comparison of TBL and lecturing

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	**p-value**	t	df	p-value (2-tailed)	Mean difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Difference	Equal Variances Assumed	5.185	**.029**	-3.885	38	.000	-15.35354	3.95222	-23.35439	-7.35268
	Equal variances not assumed			-3.679	25.343	.001	-15.35354	4.17332	-23.94275	-6.76432

This finding is inconsistent with the literature. Most reported comparison studies of TBL with lecturing, show a significant difference in student academic performance when using TBL (Jafari, 2014; Persky & Pollack, 2011; Koles et al. 2010; Letassy et al. 2008; Levine et al. 2004).

However, reported studies, Conway et al. (2010) and Grady (2011) did similar comparison studies showing no difference in student academic performance.

Unfortunately, no reported studies could be found where the difference in student academic performance was significantly higher with lecturing.

4.2.2 Quantitative data generated by self-reported questionnaires

Questionnaires with relevant questions were used to generate data to determine the first-year radiography students' perceptions of their engagement with TBL and the potential usefulness of TBL as a future teaching strategy.

Table 4.7 shows combined Groups' 1 and 2 responses to questions relating to TBL.

Table 4.7: Measure of engagement with TBL with combined Group 1 and 2

Questions	**Strongly agree**	**Moderately agree**	**Agree**	**Moderately disagree**	**Disagree**
1. The TBL exercise has improved my understanding of trauma of the elbow and the wrist.	65%	27%	7%	1%	-
2. I have been challenged to apply factual knowledge in solving a	68%	20%	12%	-	-

clinical problem during TBL.					
3. The contributions of the other students in my group have helped me learn during TBL.	68%	20%	10%	2%	-
4. The contributions of the lecturer have helped me learn during TBL.	82%	15%	3%	-	-
5. The TBL has been a productive use of my time.	78%	17%	5%	-	-
6. I feel TBL activities are enjoyable.	90%	7%	3%	-	-

The students reported positively on the different aspects of TBL. However, Table 4.8 shows the results when the 2 groups were separated and their reactions on TBL were compared.

Table 4.8: Comparison between Group 1 and Group 2 with regard to their engagement with TBL

Questions		**Strongly agree**	**Moderately agree**	**Agree**	**Moderately disagree**	**Disagree**
1. The TBL exercise has improved my understanding of trauma of the elbow.	**Group 1 Wrist**	45%	36%	14%	5%	-
	Group 2 Elbow	83%	17%	-	-	-
2. I have been challenged to apply factual knowledge in solving a clinical problem during TBL.	**Group 1 Wrist**	59%	23%	18%	-	-
	Group 2 Elbow	78%	17%	5%	-	-
3. The contributions of the other students in my group have helped me learn during TBL.	**Group 1 Wrist**	55%	23%	18%	4%	-
	Group 2 Elbow	83%	17%	-	-	-
4. The contributions of the lecturer have helped me learn during TBL.	**Group 1 Wrist**	68%	27%	5%	-	-
	Group 2 Elbow	100%	-	-	-	-
5. The TBL has been a productive use	**Group 1 Wrist**	59%	32%	9%	-	-

of my time.	**Group 2 Elbow**	100%	-	-	-	-
6. I feel TBL activities are enjoyable.	**Group 1 Wrist** **Group 2 Elbow**	82% 100%	14% -	4% -	- -	- -

The responses of the students in Group 2 who did TBL intervention for anatomy of the elbow were similar to the responses of the students' combined responses. However, the students in Group 1 who participated in a TBL intervention for the anatomy of the wrist rated their responses lower than Group 2 and the combined groups' responses.

The students were also invited to write short comments on their experiences with regard to the TBL session. The following four themes emerged from their comments:

- TBL as a study method for anatomy
- Group/team learning
- The enjoyment of TBL activities
- Concerns about implementing TBL.

The verbatim responses of the students regarding the feedback on the four themes are summarised in Table 4.9.

Table 4.9: Students' verbatim responses

<u>**Different themes**</u>	<u>**Verbatim Quotes**</u>
TBL as a study method for anatomy	• W 6: "I really feel this is a great way of learning to understand. It should be done often. Great work." • W 11: "TBL helps you understand better and think harder."

	• E 7: "The team exercises made it easier to understand how to analyse the anatomy of the views." • E 4: "This exercise was very helpful with anatomy and very productive."
Group/team learning	• W 5: "Its (sic) better to learn in a group, this way if you don't understand something you can always discuss it and understand it better." • W 12: "It helps me to learn from the knowledge of other people in my group and also to learn from each other's mistakes." • W 1: "Good to hear other opinions and discuss it together." • E 9: "The group work has helped me a lot." • E 2: "It was nice to see that in a group we can get more answers."
The enjoyment of TBL activities	• W 4: "Really enjoyed anatomy ...." • W 2: "I had a great time and really enjoyed it. I think it should be done more often." • W 3:

	"It's very good! THANKS." • E 5: "I would strongly agree with this learning skill. It is enjoying (sic), fun and learning at the same time. Makes studying fun."
Concerns about implementing TBL	• W 8: "(It's) not going to work without lectures beforehand." • W 1: "..... but it can/could get out of hand if not controlled correctly."

From these quotes it seems clear that the students experienced TBL as promoting learning to understand the factual content and the application of knowledge. The students also became aware of the value of learning in groups. The majority of students indicated that they found TBL activities enjoyable and one student stated that TBL activities are the future.

Reported studies from Jafari (2014) and Persky & Pollack (2011) confirmed students' satisfaction with teaching and learning with TBL. Students found TBL enjoyable and indicated TBL as a promising educational strategy (Levine et al. 2004), as it enhances active learning versus passive learning in lectures. Thus, it can be said that the findings from this study are consistent with reported relevant studies from the literature.

4.2.3 Quantitative data from the interaction between TBL, lecturing and examination grades

This study also looked for any interaction between TBL, lecturing and examination grades to investigate whether academically 'strong' students, identified by achieving grades A, B or C or academically 'weak' students, identified by achieving grades D or E would benefit most from TBL or lecturing. Table 4.10 indicates the number of students with grades A to E.

Table 4.10: Examination grades division

	TBL	Lecture
A (80 – 100%)	6	6
B (70 – 79%)	7	7
C (60 – 69%)	11	11
D (50 – 59%)	10	10
E (< 50%)	6	6
	N = 40	N = 40

As demonstrated in Figures 4.3 and 4.4 respectively, the academically 'strong' students (n = 6) with an examination grade of A benefitted significantly better (p = .021) from lecturing versus TBL as a teaching tool.

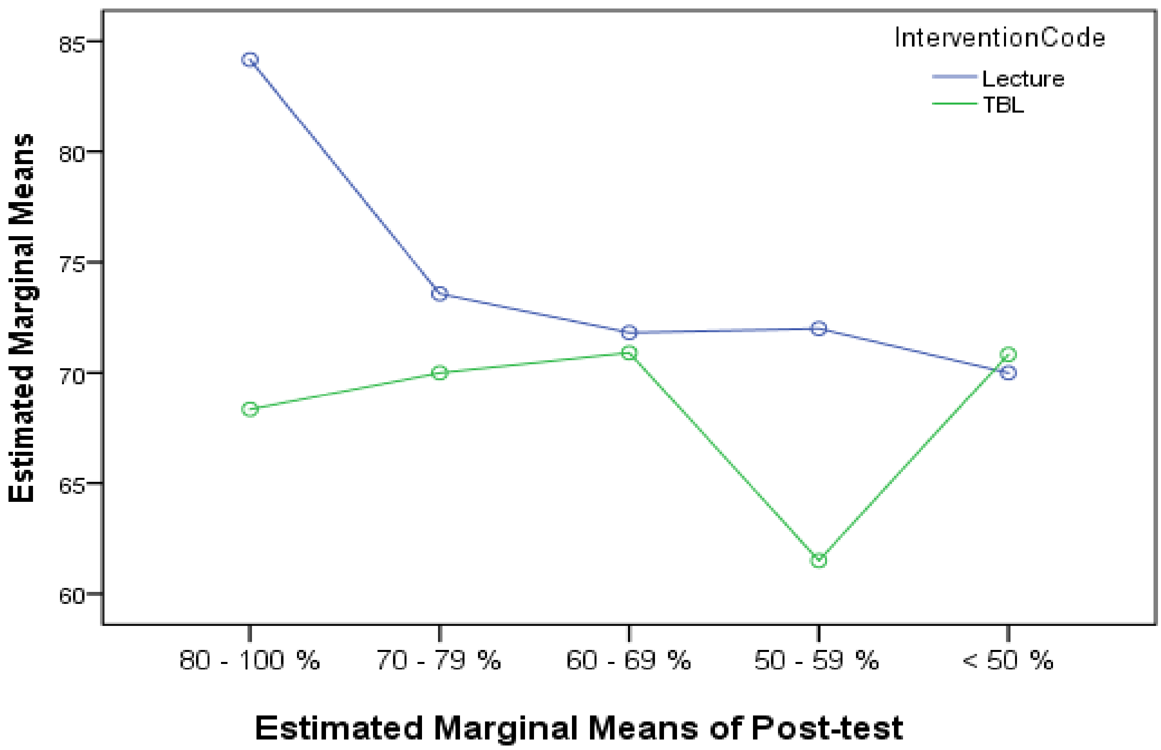

Figure 4.3: Interaction between examination grades, TBL and lecturing

The academically 'weak' group of students (n = 10) with an examination grade of D also benefitted significantly (P = .046) from lecturing versus TBL as a teaching strategy.

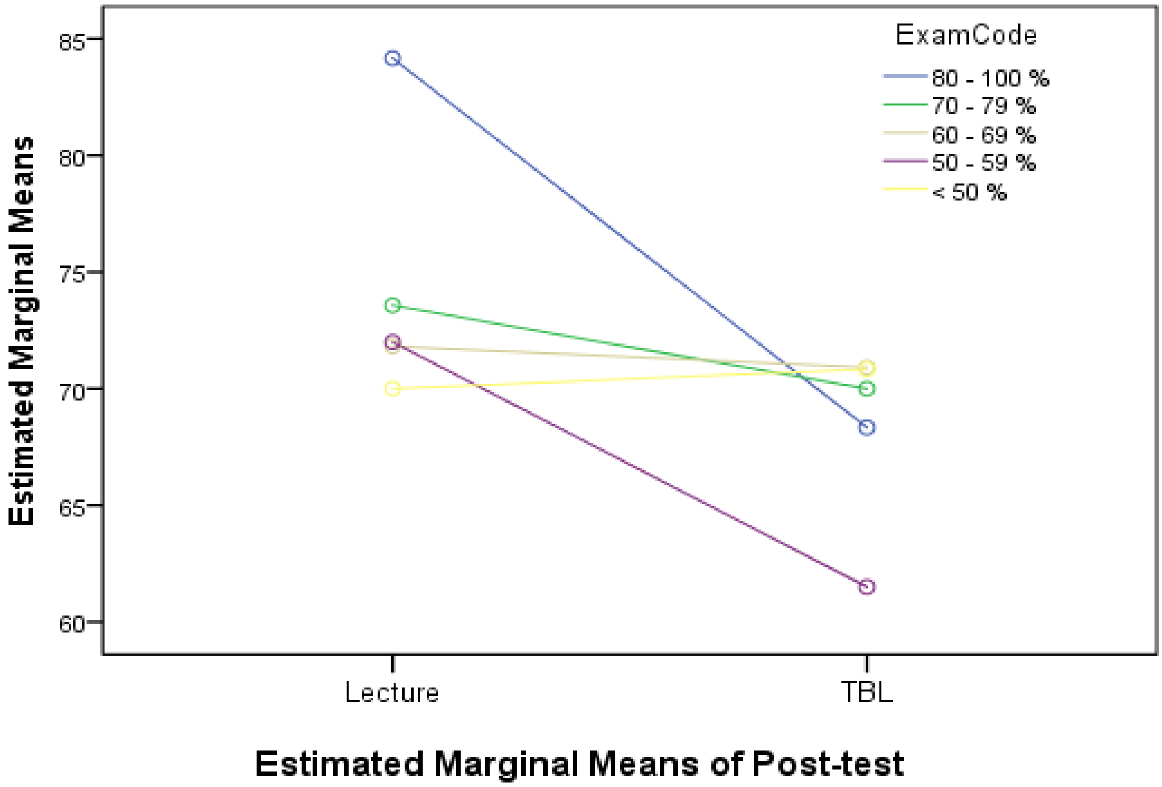

Figure 4.4: Comparison between examination grades, TBL and lecturing

The students with B and C examination grades benefitted from lecturing, but not significantly (Grade B: p = .566; Grade C: p = .854). Students with examination grades lower than 50% (Grade E) benefitted from TBL sessions, but not significantly (p = .901).

This finding is inconsistent with reported studies from the literature with regard to student satisfaction. A reported study by Koles et al. (2010) analysed student academic performance and revealed that the lowest-quartile students had 7.9% higher scores with TBL than highest-quartile students who achieved only 3.8% higher scores with TBL.

Findings from other studies conducted by Letassy et al. (2008) and Nieder, et al. (2005) supported the view that TBL provides a larger learning benefit for academically weaker students.

4.3 CONCLUSION

This chapter provided the findings from the data generated by this study.

From data it became apparent that TBL sessions were experienced by the students in a positive light.

As a teaching strategy TBL did not show any significant improvement of student academic performance, but lecturing did have a bigger impact on student academic performance for one learning outcome, anatomy of the wrist.

The data findings from the interaction between examination grades, TBL and lecturing indicated that students with examination grades, A and D benefitted significantly from lecturing. Students with examination grades, B and C benefitted also from lecturing, but not significantly. Only students with examination grades less than 50% (E) benefitted from TBL, but not significantly.

The next chapter discusses the findings and draws a number of conclusions based on the findings of this study. It also points to a number of implications that flow from its findings and conclusions.

CHAPTER 5

CONCLUSIONS AND IMPLICATIONS OF THE STUDY

5.1 INTRODUCTION

In the introductory chapter it was pointed out that anatomy constitutes one of the significant core and foundational components in health science programmes. Anatomical knowledge is a requisite for safe clinical practice, but there seems agreement that a worldwide decline in anatomical knowledge is observed. Many factors can influence the acquisition of anatomical knowledge, and relevant literature states that anatomy teaching strategies are widely debated and remain controversial to the present day (see par. 1.2). The key issue appears to be how best to teach anatomy for knowledge retention and application (Kerby et al. 2011; McLachlan et al. 2004). Different teaching strategies thus needed to be evaluated to adapt teaching to best equip healthcare professionals for clinical work with strong underlying theoretical knowledge.

In correspondence with this need, the researcher wanted to investigate whether the academic performance of radiography students could be improved by employing a teaching strategy that teach them to know and understand anatomy better and to be able to apply it clinically as well as to evaluate it radiographically.

In support of this, two research aims were posed:

- To determine the relative influence of two different teaching strategies, namely TBL and lecturing, on the academic performance of undergraduate radiography students in their anatomy studies.
- To explore participating anatomy students' perceptions of their engagement with TBL and the potential usefulness of TBL as a teaching tool. This included whether academically weaker students, as identified by their examination grades, might benefit (or not benefit) more from the use of TBL.

In Chapter 4, the empirical findings from the quantitative data generated in a quasi-experimental research design were reported. The quasi-experiment consisted of the convenience sample of 40 National Diploma in Radiography first-year students in anatomy studies at CPUT.

In this final chapter, the findings related to the research aims are summarized, conclusions are drawn and implications of the findings are pointed out. The limitations of the study are also discussed.

5.2 CONCLUSSIONS AND DISCUSSIONS

The quantitative findings of this study are the result of the measurement and comparison of student academic performance while implementing two different teaching strategies with regard to two learning outcomes.

One conclusion drawn from the findings of this study is that TBL did not prove to have a significant impact on the improvement of participant anatomy students' academic performance (see Table 4.3 (elbow anatomy) and Table 4.6 (wrist anatomy) respectively for *p*-value of TBL and lecturing comparison). This finding is inconsistent with the literature (Jafari, 2014; Persky & Pollack, 2011; Koles et al. 2010; Letassy et al. 2008 and Levin et al. 2004) where significantly better student academic performance was achieved when using TBL instead of lecturing. In hindsight, the anatomy lecturer, who was also the researcher in this study, was relatively inexperienced with TBL and might have been biased towards lecturing, as she was more comfortable with and experienced in that teaching strategy. This could have influenced the research results.

Another important conclusion from the findings relates to the outcome of the assessments to determine the students' academic performance (see Figure 4.1 (elbow anatomy) and Figure 4.2 (wrist anatomy) respectively for the mean % changes in pre- and post-test scores). As mentioned before, the facilitator (researcher) has limited experience with TBL and this could have influenced the ability to develop an appropriate level of RAT questions as well as appropriate application exercises for the specific content. The formal assessment, the pre-test before the implementation of TBL and the post-tests after the implementation of TBL could have been another potential problem. The pre-and post-tests consisted of questions to test the knowledge of the advance preparation, but it also constitutes the format to test knowledge when lecturing. On the other hand, TBL is based on application of the knowledge of the content and perhaps more appropriate methods of testing student academic performance would be to make use of case studies or clinical scenarios. This would test the students' ability to apply knowledge and therefore provide a more realistic picture of TBL on learning outcomes.

It is thus suggested that, in hindsight, the following assessment process should have been followed:

- A pre-test on the knowledge of the advance preparation of the two learning outcomes
- A TBL or lecturing intervention for each of the learning outcomes
- A post-test on the application of the content knowledge e.g. a case study.

These results might have contributed to a more accurate reflection of the value of either the TBL or lecturing mode.

Literature points to the fact that students potentially learn more when actively involved in the learning environment (Mann, 2011). TBL as an active student-centered teaching strategy with the combination of advance preparation, the interaction with peers and the reinforcement of the content created the expectation that TBL would improve student academic performance (Parmelee et al. 2012). On the other hand, lecturing mainly represent a passive process (Young, 2009) offering students low levels of engagement, which may lead to surface learning and content transmission (Di Leonardi, 2007; Jones, 2007) and would not necessarily improve students' academic results.

Radiography students are traditionally taught with lecturing at CPUT and the findings from the study indicate how entrenched traditional teaching strategies are in higher education, resulting in students who expect to learn passively. The findings thus illustrate that students might be hesitant to adopt TBL as a learning strategy, largely explaining why TBL did not improve the student academic performance (see figure 4.2 (wrist anatomy) for the significant mean % changes in pre- and post-test score for lecturing). What became apparent was that 'new' teaching strategies other than lecturing seem to make students fear that they will miss out on important information. Another factor for this conclusion may be that students did not recognize the importance of the all importance of advanced preparation.

Furthermore, from the findings related to the feedback questionnaires it can be concluded that the students were engaged both individually and in a team situation with the guidance of the lecturer when using TBL in the classroom (see Table 4.7 for more information). The students thus grappled with the understanding and application of knowledge with the help of their peers, which is an important characteristic of active student-centered learning. This finding is consistent with the literature (Clark et al. 2008; Dana, 2007; Haidet et al. 2002 and Levine et al. 2004) that indicates the need for and value of student-centered learning.

From the findings one may also conclude that participant students actually enjoyed learning via the TBL mode (see Table 4.7 and Table 4.9 respectively for more information). This conclusion corresponds with other findings on student enjoyment of TBL and constitutes a frequent theme in the literature (Dana, 2007; Levine et al. 2004 and Seidel & Richards, 2001).

A further conclusion is that students favourably perceived TBL as a future study strategy for anatomy, but that their concerns about the implementation of TBL also emerged. The students were concerned about the lack of lectures, the possibility of missing important information and the inability of knowing key concepts to focus on. This conclusion ties in with the first conclusion where the students also preferred lecturing to TBL for better academic results, in spite of the fact that they recognized the benefits of TBL (see Table 4.9 for more information). Students seem to prefer learning passively, with the lecturer as a source of information rather than a facilitator of learning processes (Clark et al. 2008).

A final conclusion of this study is that academically weaker students do not necessarily learn more from TBL than from traditional lectures. This is in contrast with relevant literature (Koles et al. 2005; Koles et al. 2010; Letassy et al. 2008 and Tan et al. 2011) that indicates that academically weaker students benefitted more from TBL. Reasons for this phenomenon were stated as reinforcement of knowledge, active participation and engagement with TBL. In this study, however, students with an examination grade E benefitted from TBL, but not significantly. The students who had A, B, C and D examination grades benefitted from lecturing, some significantly, but others less so (see Figure 4.4 for more information).

5.3 IMPLICATIONS

The findings and conclusions from this study may have a number of implications related specifically to the influence of TBL as a teaching strategy to improve anatomical academic performance, student engagement with the learning process and future research into TBL for learning and application of content.

First-year radiography students are mostly accepted straight from secondary schooling and they have traditionally been taught with lecturing, a passive unengaged process with the teacher as the provider of information. The implication of this study is that anatomy students may benefit from a changed mindset towards learning whereby they can appreciate and adopt a new teaching strategy for active learning with advanced preparation work, learning from peers and learning to apply learnt knowledge. The relevant department will thus have to state the policy of using TBL for facilitating learning of Anatomy 1, which needs to be reflected in study guides. One implication of such an approach might be to have a TBL workshop with TBL exercises during orientation for the first-year students. A week before the workshop, the students need to start with advanced preparation for the workshop by familiarizing themselves with issues such as what TBL is, its principles, its practices as well as its advantages and challenges.

Students will therefore be randomly selected into teams and the first day in class will start with the RATs (IRAT and GRAT) followed by instructor feedback. The teams will be given application exercises on TBL concepts and discuss possible outcomes to the stated problems in order to make a decision and defend it to the other groups. The facilitator should provide the correct solutions with the necessary motivation. Such preparation might provide students with the necessary insight into TBL as a teaching strategy. At the same time, the department will also have to have the buy-in of the lecturers and they will have to be trained to manage TBL.

Another implication, if TBL is to be promoted, is that material development will have to take place, which might be expensive in terms of resources. Advance preparation work for students must be created in units covering any given learning outcome, RATs will have to be set and appropriate application exercises will have to be written. Additional to more lecturer time required, administrative assistance will be needed for the marking and administration of the process.

The implication of implementing TBL in anatomy teaching and learning is that by the nature of TBL, the students might become more engaged with understanding and applying anatomical knowledge while working in teams. The assumption may also be that academically weaker students will learn more in teams and thus benefit more from TBL, although in this study the findings did not support such an assumption.

5.4 STUDY LIMITATIONS

As no study is perfect, one needs to also point out the limitations of this study. Lunenburg and Irby (2008) report that the causes of unexpected results of research usually fall into three categories: sampling, instrumentation and/or research design. This study had a small sample of only 40 students participating at one university of technology. A larger group of students over a longer period of time at more universities may provide better results for a more generalized view on the possibilities of TBL in anatomy teaching and learning.

In this study a modified version of the true TBL process was used because peer evaluation was not implemented. If the study was done over a longer period of time, peer evaluation might have added significant value as formative assessment of accountability and interpersonal skills that are important elements of TBL.

The researcher's experience with the implementation of TBL in this study was relatively limited, especially in the development of the Readiness Assurance Tests and in application exercises. Both these factors may have impacted student responses and the results of the project. The pre- and post-tests used as instrumentation could have been problematic, because the content was the same for both tests and included mostly recalling of facts.

Finally, the students knew the outcome of the research would not be part of their final assessment marks and therefore they may not have put sufficient effort into the required advance preparation.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

TBL has the potential to turn anatomy studies for radiography into a structured, student-centered learning environment, but more research is needed to establish this innovative teaching strategy. The following research agenda could be applicable:

- An exploration of the continuing improvement of academic knowledge and also the continuing improvement after 48hours or longer
- Inquiry into the relationship between accountability and the level of student engagement
- Research into the issue of whether more self-directed learning may promote high engagement in TBL
- Investigating the possible link between the results of IRAT and GRAT and students' academic performance
- Research into peer evaluation to overcome TBL barriers and let students see the potential of objective peer input
- Inquiry into whether lecturer development will promote the TBL process
- Exploring whether the use of TBL actually improve clinical work

5.6 Conclusion

The findings of this study clearly and confidently did not reflect reported results from the existing literature on comparisons between TBL and lecturing, nor did it prove beyond doubt any academic benefits to anatomy students.

However, the results of this study did indicate that students taught by TBL reported better engagement with learning anatomical content and content application. At a time when higher education calls for creating an active, student-centered learning and engaging environment to produce learning (Barr & Tagg, 1995), this constitutes a positive finding.

An important challenge in medical education is to prepare graduates who are accountable for their own learning and will become healthcare professionals who know the body's anatomy and to apply their knowledge. Therefore, the researcher is convinced of the inherent value of TBL as a teaching and learning strategy, but only if implemented over a longer period of time for students to experience the real value and impact of this strategy.

In the interim, however, TBL and lecturing both have a place in teaching anatomy to undergraduate radiography students to improve their academic performance and to create a safe practice for the patients in their care.

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ADDENDUM A:

PARTICIPANT INFORMATION AND CONSENT FORM

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot · your knowledge partner

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Team-based learning versus the lecture in undergraduate anatomy studies: An interventional study.

You are asked to participate in a research study conducted by H J Boshoff, Higher Diploma Radiotherapy and Teaching from the Faculty of Education – Curriculum Studies at Stellenbosch University. The results of this intervention will contribute to a thesis for a MPhil masters degree. You were selected as a participant in this study because you are part of the selected anatomy class for this intervention.

1. PURPOSE OF THE STUDY

The objective of this research study is to compare two different teaching methods, team-based learning and the lecture, to determine which method has the greater impact on improvement of knowledge in radiographic anatomy education.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following things:

1. Do prescribed assigned reading about 6 anatomical learning outcomes
2. To write a multiple choice question test about the assigned reading
3. To attend a team-based learning session
4. To attend a lecture
5. To write a multiple choice question test about the assigned reading

The duration of the study is one day plus the preparation time (reading).

3. POTENTIAL RISKS AND DISCOMFORTS

No known risks or discomforts.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The information collected will not directly benefit you, but it will help future teaching and learning strategies for anatomy to improve the pass rate and knowledge retention.

5. PAYMENT FOR PARTICIPATION

There is no financial compensation for your participation in this study.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of safekeeping by the researcher of all data information instruments and destroyed on presentation of the study.
The results of the study may be published for scientific purposes, but will not give your name.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact

<u>Researcher:</u>
H J Boshoff
Radiography
Tygerberg Campus
Tygerberg
Tel 021 932 7320

<u>Supervisor:</u>
Prof E Bitzer
Faculty of Education
Stellenbosch University
021 808 2277

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to

by H J Boshoff in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to participate in this study. I have been given a copy of this form.

Name of Subject/Participant

_______________________________________ _____________________

Signature of Subject/Participant **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to

[Name of Subject/Participant]

He/she was encouraged and given ample time to ask me questions. This conversation was conducted in English.

_______________________________________ _____________________

Signature of Investigator **Date**

ADDENDUM B:

CPUT CONSENT FORM

Cape Peninsula University of Technology

Radiography Department
Faculty of Health and Wellness Sciences
Cape Peninsula University of Technology
P O Box 1906
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21 September 2012
Tel: +2721-9596274
hassans@cput.ac.za

Professor E M Bitzer
Director: Centre for Higher and Adult Education
Curriculum Studies
Faculty of Education
University of Stellenbosch

Dear Professor Bitzer

Masters Degree in Philosophy of Higher Learning: H J Boshoff
Professional Position: Radiography Lecturer
CPUT Personnel number: 30001499

It is noted that the following Research Proposal, towards the completion of the above degree at the University of Stellenbosch, has been provisionally approved by the University of Stellenbosch Research committee, pending CPUT approval.

Team- Based learning versus the lecture in undergraduate anatomy studies

The Cape Peninsula University of Technology hereby supports the above research and gives permission to Mrs H Boshoff to undertake the research involving the first year Radiography students at the Tygerberg Campus of CPUT as per the proposal.

Yours truly,

Shafick Hassan
[HOD: Radiography]

ADDENDUM C: READING ASSIGNMENT

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

Anatomy 1

What are we doing?

We are investigating traumatic injuries to the elbow and wrist!

In order to reach the learning outcomes for this section of anatomy, you must please read the following -

Reading for the distal end of the humerus, the elbow, the radius and ulna and the wrist

Learning outcomes

1. Define a fracture
2. Classify different fractures
3. Discuss possible complications of fractures

Elbow –

1. Describe the bones and joints of the elbow
2. Identify the anatomical components of the elbow on normal radiographic views
3. Describe different fractures of the elbow
4. Identify features of fractures of the elbow on x-ray images
5. Compare different but similar fractures of the elbow

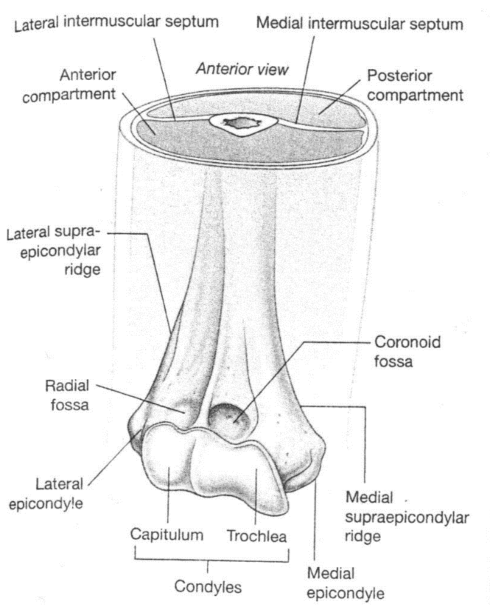
Wrist –

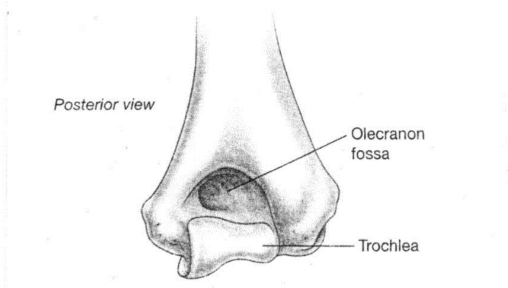
1. Describe the bones and joints of the wrist
2. Identify the anatomical components of the wrist on normal radiographic views
3. Describe different fractures of the wrist
4. Identify features of fractures of the wrist on x-ray images
5. Compare different but similar fractures of the wrist

The Distal End of the Humerus

Distally, the humerus becomes flattened and these borders expand as

- the lateral supracondylar ridge = more pronounced, attachment for muscles
- the medial supracondylar ridge – attachment for muscles





Distal end of the humerus.

The distal end of the humerus, which is flattened in the anterioposterior plane, bears

1 condyle	**2 epicondyles**	**3 fossae**
Has 2 articular parts – 1. capitulum articulates with radius 2. trochlea articulates with ulna Lies medial to capitulum and extends onto the posterior surface of the humerus.	1. Lie adjacent and superior to the trochlea and capitulum. The medial epicondyle is large and has a large ovel impression for muscle attachments. The ulnar nerve passes around the posterior surface of the medial epicondyle. 2. The lateral epicondyle is lateral to the capitulum and has a large irregular impression for muscle attachment.	Superior to the trochlea and capitulum on the distal humerus. 1.the radial fossa – Immediately superior to the capitulum and on anterior humerus. The smallest. 2.the coronoid fossa – Adjacent to the radial fossa and superior to the trochlea. 3.The olecranon fossa – Immediately superior to the trochlea on the posterior distal humerus. The biggest. These 3 fossae accommodate projections of the forearm.

Proximal End of the Radius

The proximal end of the radius consists of a head, a neck and the radial tuberosity.

The head of the radius is

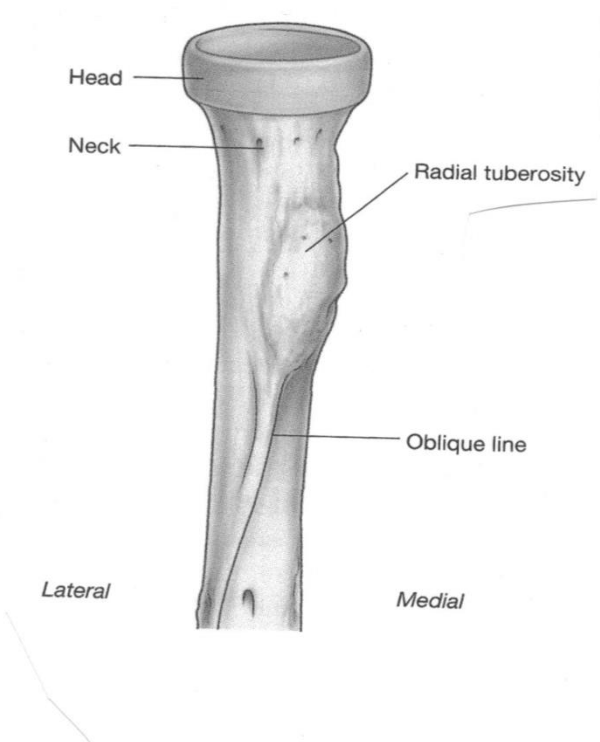
- A thick disc-shaped structure
- The circular superior surface is concave for **articulation with the capitulum** of the humerus.
- The thick margin of the disc is broad medially where it **articulates with the radial notch** on the proximal end of the ulna.

The neck of the radius is

- A short and narrow cylinder of bone between the expanded head and the radial tuberosity on the shaft.

The radial tuberosity is

- A large blunt projection on the medial surface of the radius immediately inferior to the neck. Much of its surface is roughened for the attachment of the biceps brachii tendon.



Anterior view of the proximal end of the radius.

Proximal End of the Ulna

The proximal end of the ulna is much larger than the proximal end of the radius and consists of the olecranon, the coronoid process, the trochlear notch, the radial notch and the tuberosity of ulna.

The olecranon is a

- Large projection of bone that extend proximally from the ulna.
- Its anterolateral surface is articular and contributes to the formation of the **trochlear notch**, which **articulates with the trochlea** of the humerus.
- The superior surface is marked by a large roughened impression for the attachment of the triceps brachii muscle.
- The posterior surface is smooth, shaped somewhat triangular, can be palpated as the 'tip of the elbow'.

The coronoid process

- projects anteriorly from the proximal end of the ulna.

The trochlear notch

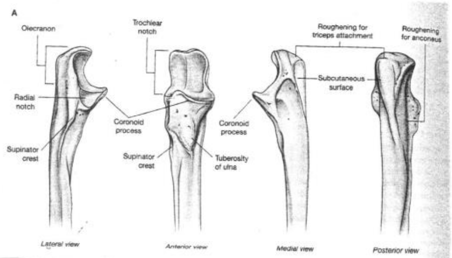
- Its superolateral surface is articular and participates, **with the oleranon, in forming the trochlear notch.**

The radial notch

- The lateral surface is marked by **the radial notch** for **articulation with the head of the radius**.
- Just inferior to the radial notch is a fossa that allows the radial tuberosity to change position during pronation and supination. The posterior margin of this fossa is broadened to form the supinator crest.

The tuberosity of the ulna

- The anterior surface of the coronoid process is triangle, with the apex directed distally, and has a number of roughenings, the tuberosity of ulna, is at the apex of the anterior surface and is the **attachment site for the brachialis muscle.**



A. Lateral, anterior, medial, and posterior views of the proximal end of the ulna.

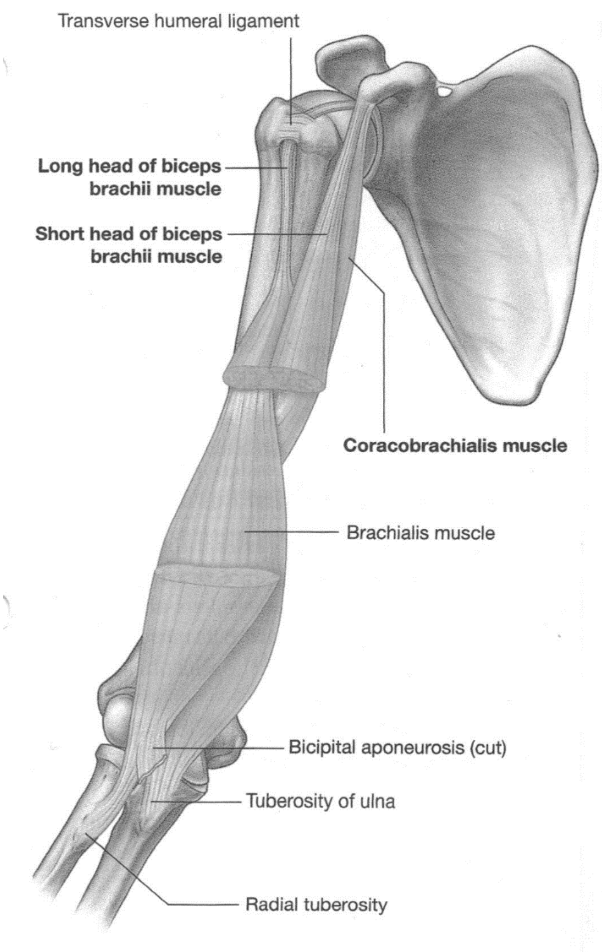
Muscles of the Humerus

The anterior compartment of the humerus contains three muscles –

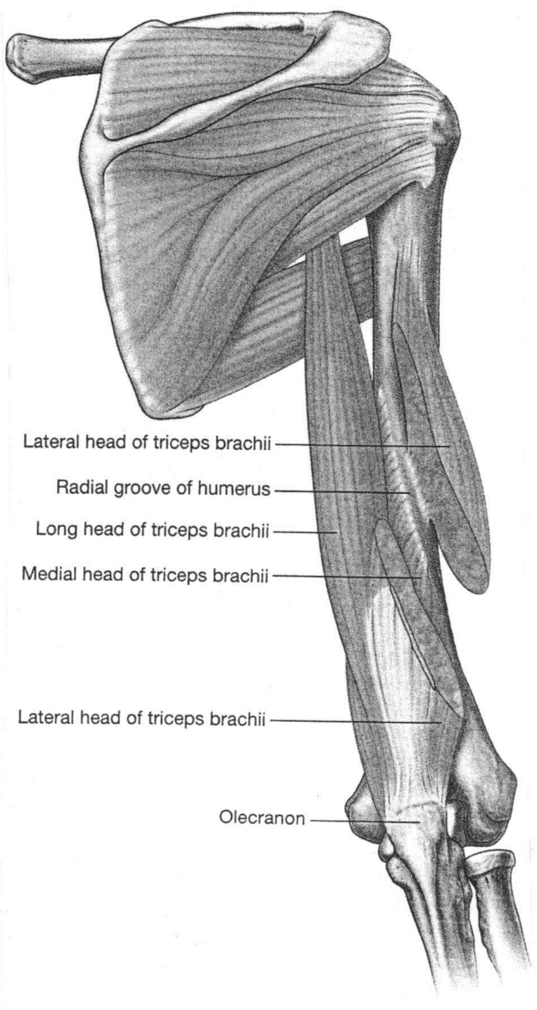
1. The coracobrachialis – insets on the linear roughening on the mid-shaft of the humerus on the medial side.
2. The brachialis - inserts on the tuberosity of the ulna.
3. The biceps brachii - inserts on the radial tuberosity

The posterior compartment contains one muscle –

1. The triceps brachii muscle - inserts on the olecranon.

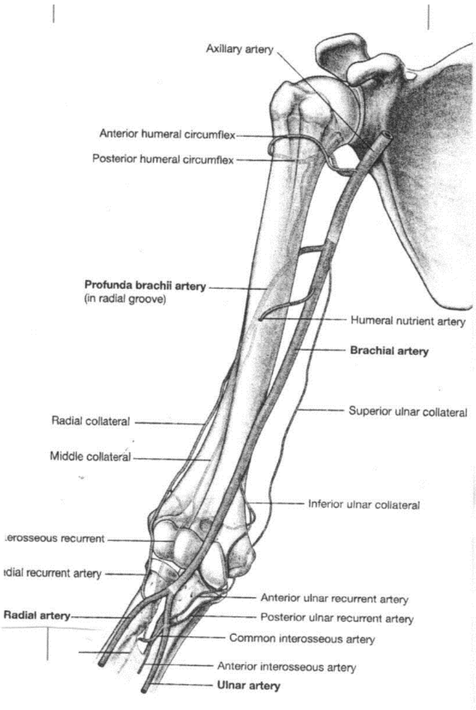


Biceps brachii and brachialis muscles.

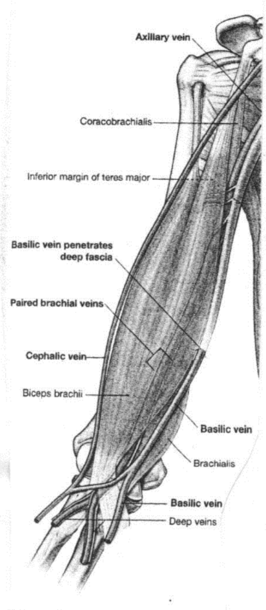


Arteries. Veins and Nerves of the Humerus

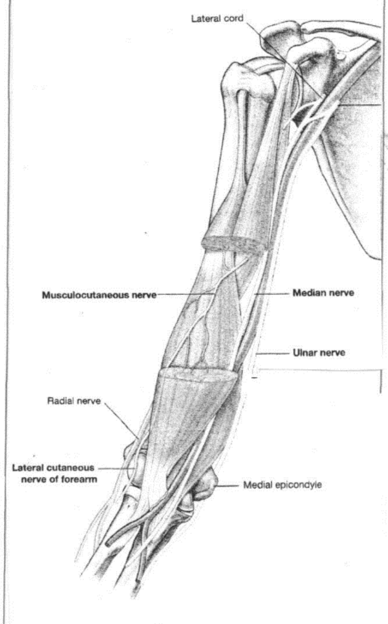
Arteries	Veins	Nerves
The major artery of the humerus ,**the brachial artery**, is found in the anterior compartment. Beginning as a continuation of the axillary artery, it **divides into the radial and ulnar arteries** just distal to the elbow. In the proximal humerus, the brachial artery lies on the medial side and in the distal arm, it moves laterally to assume a position midway between the lateral epicondyle and the medial epicondyle of the humerus. It crosses anteriorly to the elbow where it lies immediately medial to the tendon of the biceps brachii muscle.	**Paired brachial veins** pass along the medial and lateral sides of the brachial artery. Two large subcutaneous veins, the **basilic vein and cephalic vein** are also located in the upper arm. All these veins drain into the axillary vein.	The **median nerve, ulnar nerve and radial nerve** serve the upper arm. If the humerus is fractured the radial nerve may become stretched or transacted in this region and may lead to permanent damage and loss of function. In the upper arm and forearm the median nerve is usually not injured by trauma because of its relatively deep position. The commonest neurologic problem associated with the median nerve is compression beneath the flexor retinaculum at the wrist (carpal tunnel syndrome).



Brachial artery. B. Branches.



Veins of the arm.



Musculocutaneous, median, and ulnar nerves in the arm.

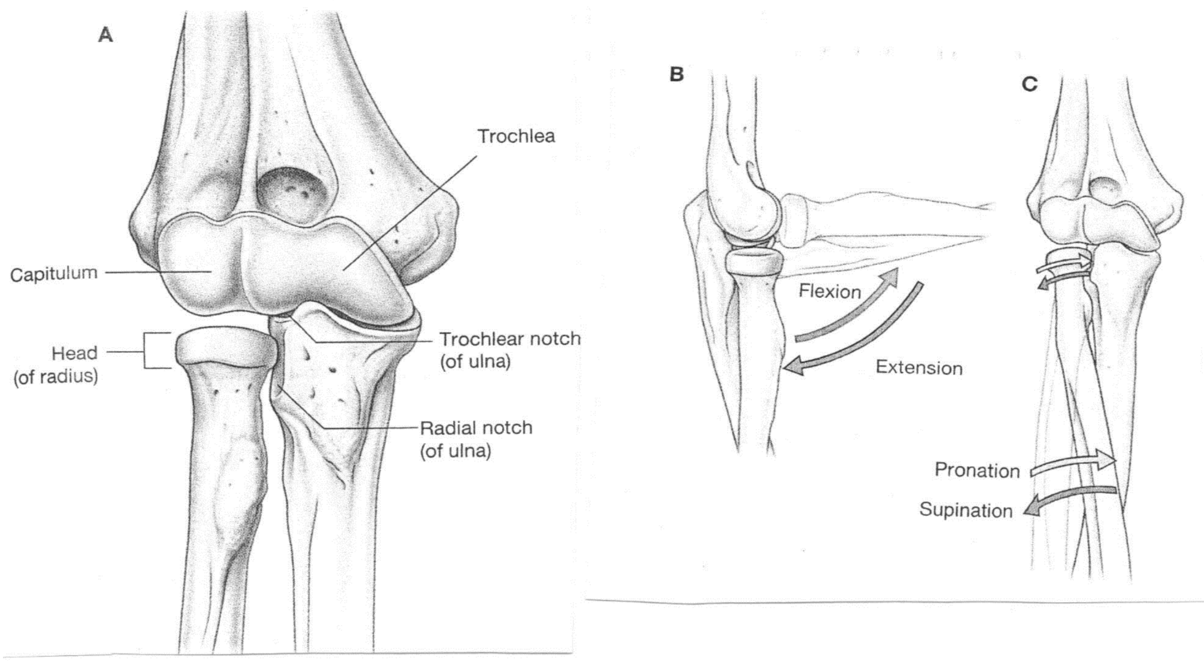
The Elbow Joint

The elbow joint is a complex joint involving three separate articulations, which share a common synovial cavity:

- The joints between the trochlear notch of the ulna and the trochlea of the humerus and between the head of the radius and the capitulum of the humerus are primarily involved with hinge-like flexion and extension of the forearm on the arm and, together, are the principal articulations of the elbow joint.
- The joint between the head of the radius and the radial notch of the ulna, the proximal radio-ulnar joint, is involved with pronation and supination of the forearm.

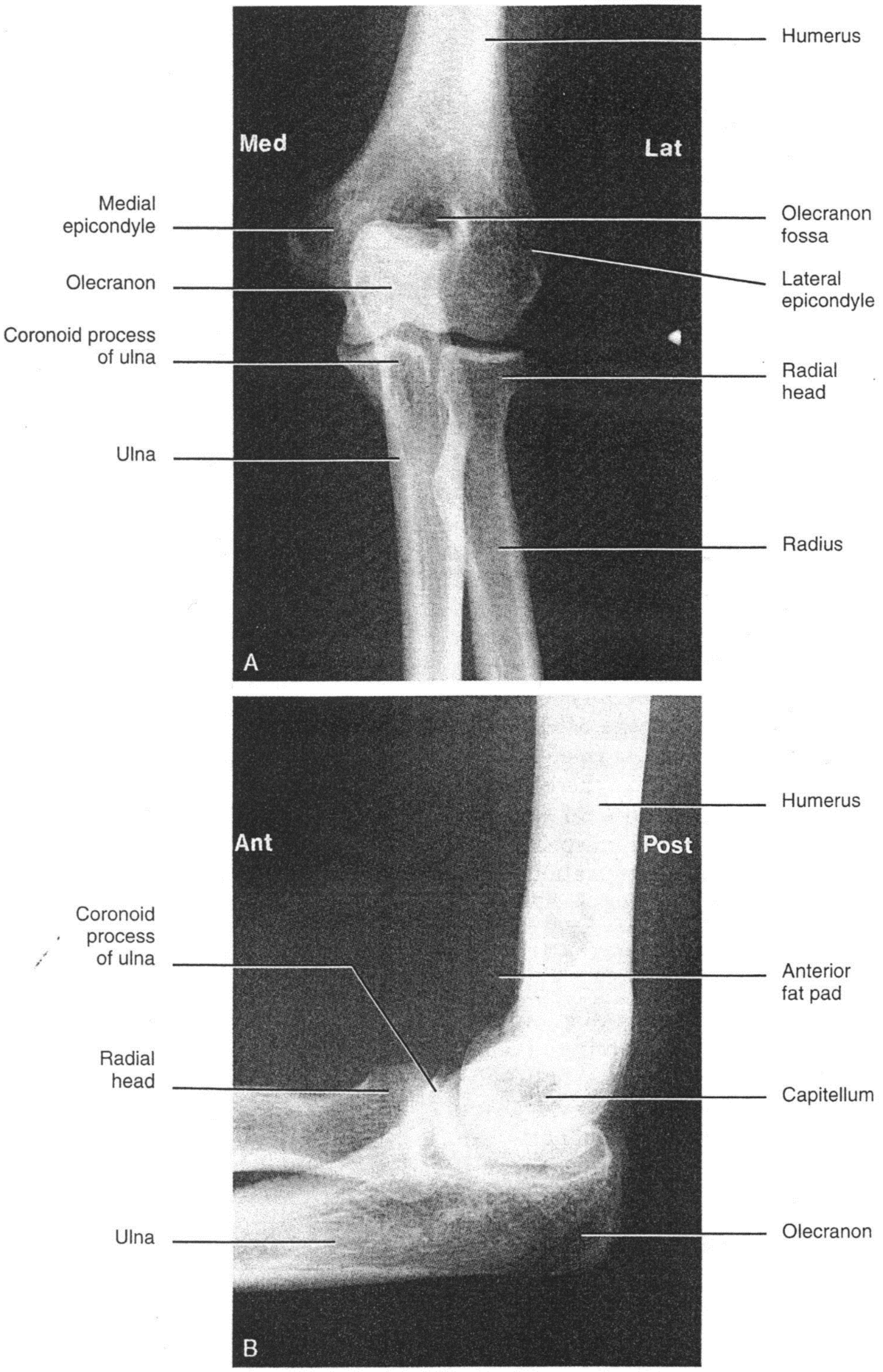
Vascular supply to the elbow joint is through an anastomotic network of vessels derived from collateral and recurrant branches of the brachial, radial and ulnar arteries.

The elbow joint is innervated predominantly by branches of the radial nerves, but there may be some innervations by branches of the ulnar and median nerves.



Components and movements of the elbow joint. **A.** Bones and joint surfaces. **B.** Flexion and extension
supination.

The Normal Radiographic Appearance of an Elbow.



Normal anatomy of the elbow in the anteroposterior projection *(A)* and in the lateral projection *(B)*.

The Forearm

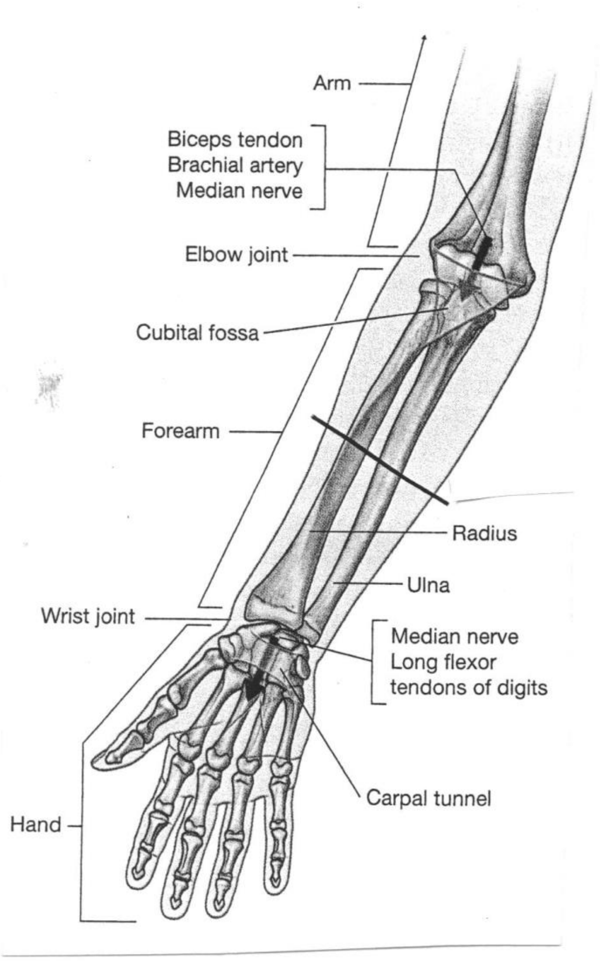
The forearm extends between the elbow joint and the wrist joint.

Proximally, most major structures pass between the upper arm and forearm through, or in relation to, the cubital fossa, which is anterior to the elbow joint. The **exception** is the ulnar nerve, which passes posterior to the medial epicondyle of the humerus.

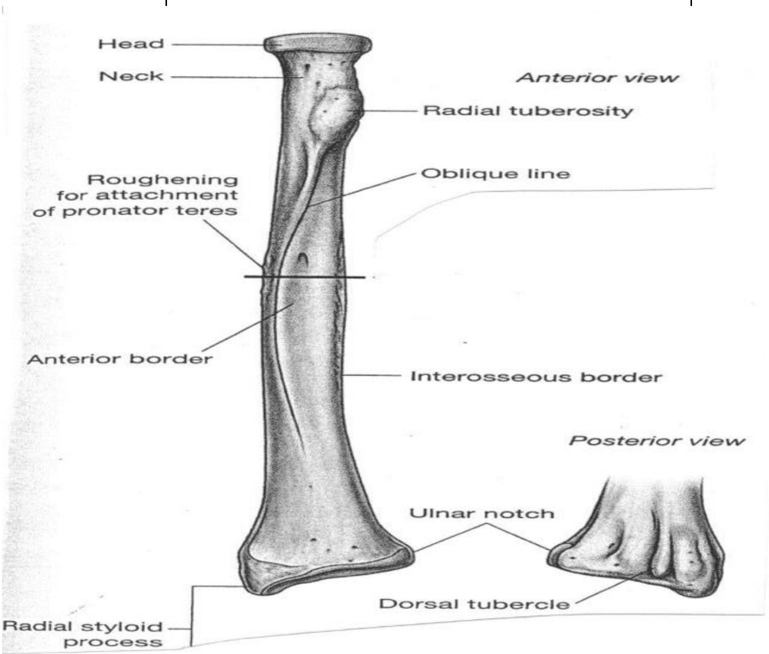
Distally, structures pass between the forearm and the hand through, or anterior to, the carpal tunnel. The **major exception** is the radial artery, which passes dorsally around the wrist to enter the hand posteriorly.

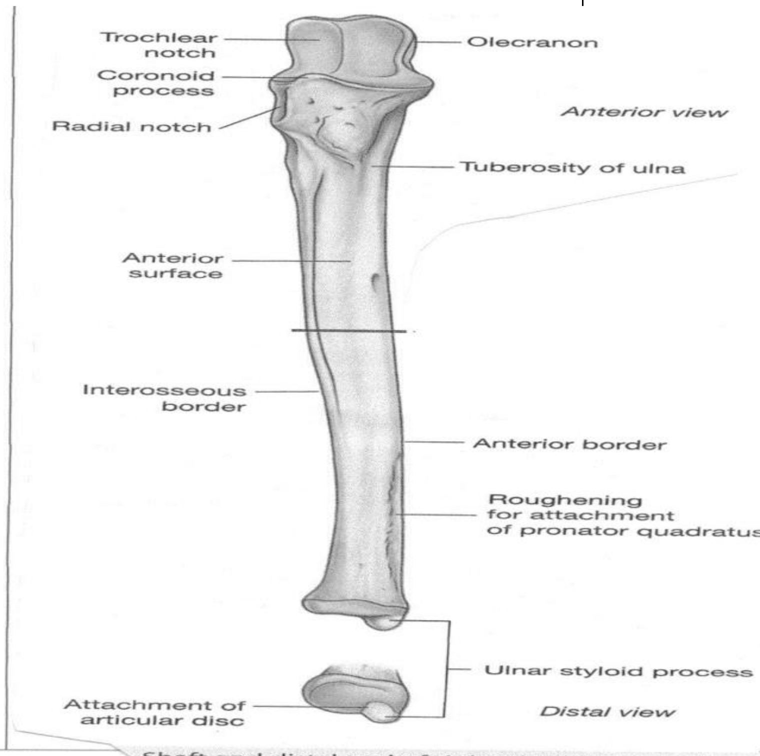
The bony framework of the forearm consists of two parallel bones, the radius and ulna. The radius is lateral in position and is small proximally, where it articulates with the humerus, and large distally where it forms the wrist joint with the carpal bones of the hand.

The ulna is medial in the forearm, and its proximal and distal dimensions are the reverse of those of the radius: the ulna is large proximally and small distally. Proximal and distal joints between the radius and ulna allow the distal end of the radius to swing over the adjacent end of the ulna, resulting in pronation and supination of the hand.



The shaft and distal end of the radius	**The shaft and distal end of the ulna**
• The shaft of the radius is narrow proximally, where it is continuous with the radial tuberosity and neck, and much broader distally, where it expands to form the distal end. • The lateral surface of the radius is diamond-shaped and extends distally as a radial styloid process. • The distal end of the radius is marked by two facets for articulation with two carpal bones, the scaphoid and lunate.	• The shaft of the ulna is broad superiorly where it is continuous with the large proximal end and narrow distally to form a small distal head. • The distal end of the ulna is small and characterised by a rounded head and the ulnar styloid process. • The anterolateral and distal part of the head is covered by articular cartilage. • The ulnar styloid process originates from the dorsomedial aspect of the ulna and projects distally.





Shaft and distal end of right ulna.

Joints

Distal radio-ulnar joint

The distal radio-ulnar joint occurs between the articular surface of the head of the ulna with the ulnar notch on the end of the radius, and with a fibrous articular disc, which seperates the radio-ulnar joint from the wrist joint.

The triangular-shaped articular disc is attached by its apex to a roughened depression on the ulna between the styloid process and the articular surface of the head, and by its base to the angular margin of the radius between the ulnar notch and the articular surface for the carpal bones.

The distal radio-ulnar joint allows the distal end of the radius to move anteriomedially over the ulna.

The interosseous membrane

The interosseous membrane is a thin fibrous sheet that connects the medial and lateral borders of the radius and ulna respectively.

Arteries, VeinsandNerves

The brachial artery enters the forearm by passing through the cubital fossa and divides into its two major branches, the radial and ulnar arteries. The radial and ulnar veins drain into the brachial vein.

The median and ulnar nerves serve the forearm.

The hand

The hand is the region of the upper limb distal to the wrist joint and it is subdivided into three parts:

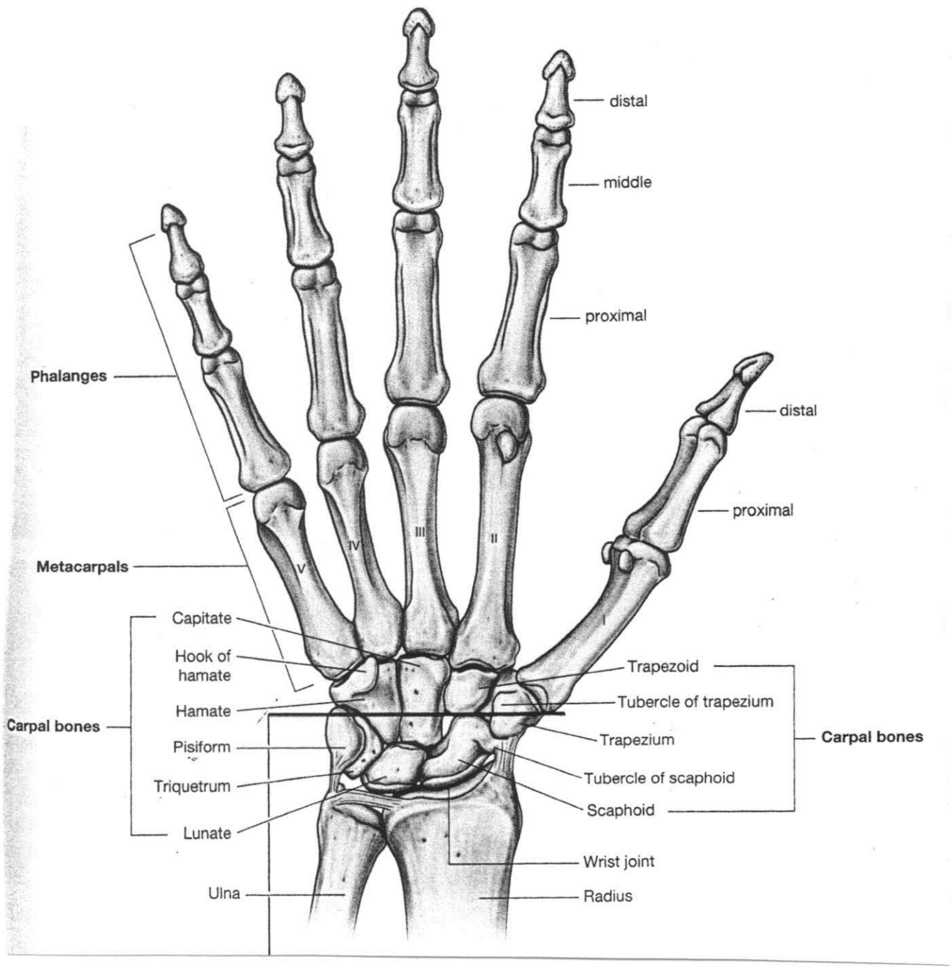
- The wrist
- The metacarpus
- The digits

The hand has an anterior surface, the palm, and a dorsal surface, the dorsum of the hand.

Bones

There are three groups of bones in the hand:

- The eight carpal bones are the bones of the wrist
- The five metacarpals (I to V) are the bones of the metacarpus
- The phalanges are the bones of the digits – the thumb has only two and the rest of the digits have three



The Carpal Bones

The small carpal bones of the wrist are arranged in two rows, a proximal and distal row, each consisting of four bones.

The proximal row

Beginning on the lateral, or thumb, side is the **scaphoid**, a boat-shaped bone, is the largest bone in the proximal row and articulates with the radius proximally. Its location and articulation with the forearm makes it an important radiographically because it is the most frequently fractured carpal bone.

The lunate, moon-shaped, is the second carpal in the proximal row and also articulates with the radius. It is distinguished by the deep concavity on its distal surface, where it articulates with the capitates of the distal row of carpals (best seen in anterior view).

The third carpal is the **triquetrum,** which has three articular surfaces and is distinguished by its pyramidal shape and anterior articulation with the small pisiform.

The pisiform, pea-shaped, is the smallest of the carpal bones and is located anterior to the triquetrum, most evident in the carpal sulcus view.

The distal row

Starting on the lateral, or thumb, side is the **trapezium**, a four-sided, somewhat irregular shaped bone located between the scaphoid medially and the first metacarpal distally.

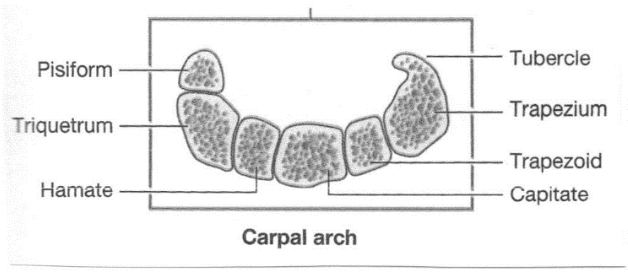
The wedge-shaped **trapezoid**, also four-sided, is the smallest bone in the distal row.

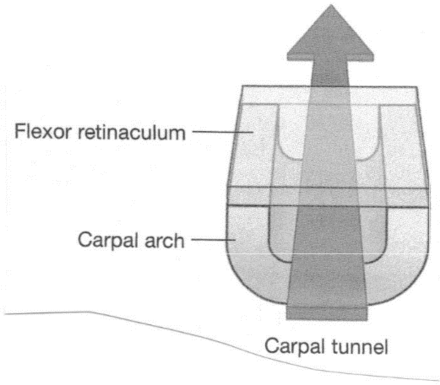
This bone is followed by the largest of the carpal bones, the **capitate**. It is also identified by its large rounded head that fits proximally into a concavity formed by the scaphoid and lunate bones.

The last carpal bone in the distal row is the **hamate,** which is easily distinguished by the hooklike process called the hamulus, projecting from its palmar surface.

The carpal tunnel view

The carpal bones do not lie in a flat coronal plane, rather, they form an arch, whose base is directed anteriorly. The lateral side of this base is formed by the tubercles of the scaphoid and trapezium. The medial side is formed by the pisiform and the hook of the hamate. The flexor retinaculum (a thick connective tissue ligament) attaches to, and spans the distance between, the medial and lateral sides of the base to form the anterior wall of the so-called carpal tunnel. The sides and roof of the carpal tunnel are formed by the arch of the carpal bones. The space carries the tendons of several muscles and the median nerve.





The metacarpals

Each of the five metacarpal bones is related to one digit:

- Metacarpal I is related to the thumb
- Metacarpals II to V are related to the index, middle, ring and little fingers, respectively.

Each metacarpal consists of a base, a shaft and distally, a head.

All the bases of the metacarpals articulate with the carpal bones.

Joints

Wrist joint

The wrist joint is a synovial joint between the distal end of the radius and the articular disc overlying the distal end of the ulna, and the scaphoid, lunate and triquetrum.

The carpal joints

The synovial joints between the carpal bones share a common articular cavity.

The carpometacarpal joints

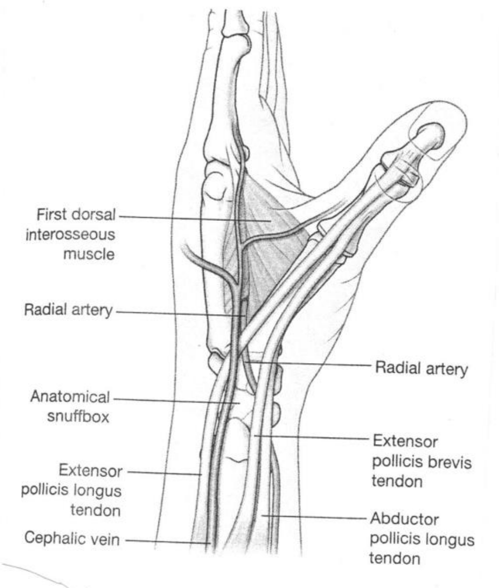
There are five carpometacarpal joints between the metacarpals and the related distal row of carpal bones.

The anatomical snuffbox

The 'anatomical snuffbox' is a term given to the triangular depression formed on the posterolateral side of the wrist and metacarpal I. The base of the triangle is at the wrist and the apex is directed to the thumb.

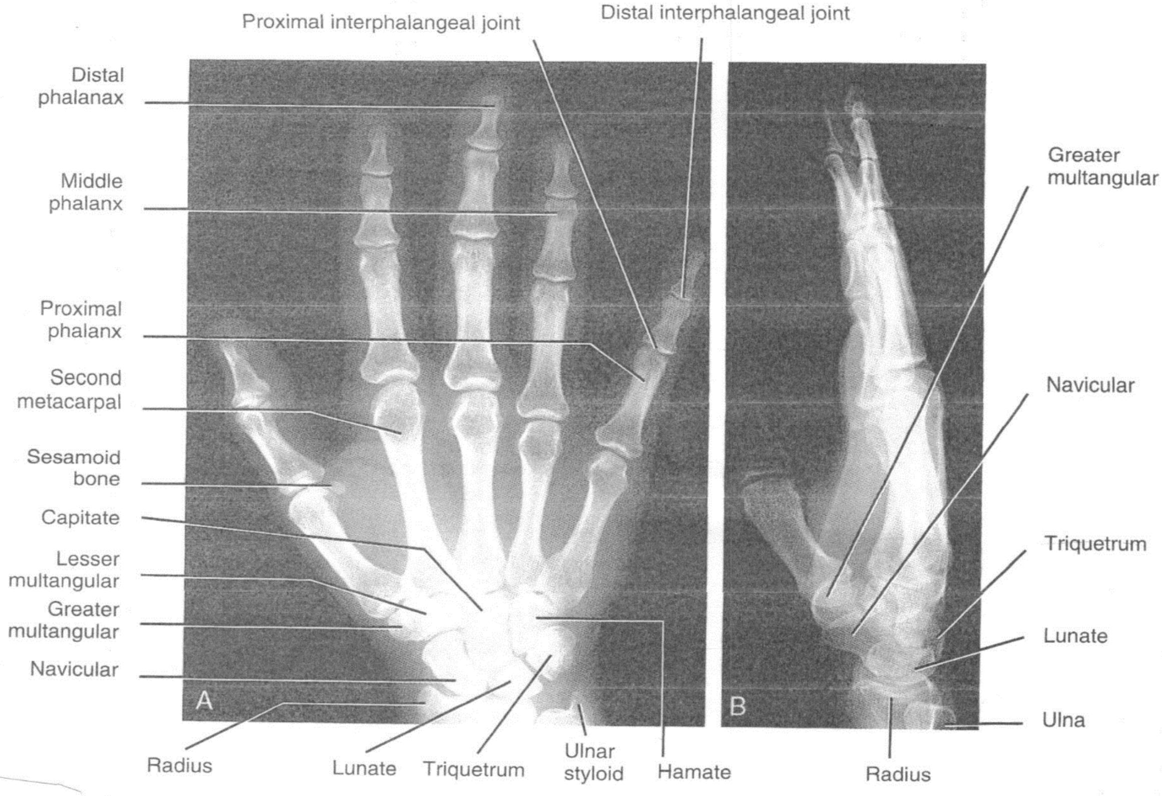
The radial artery passes obliquely through the anatomical snuffbox and lies adjacent to the sccaphoid and trapezium.

The anatomical snuffbox is an important clinical region. When the hand is in ulnar deviation, the scaphoid becomes palpable within the snuffbox. This position enables the doctor to palpate the bone to assess for a fracture.



Anatomical snuff box.

The Normal Radiographic Appearance of a Wrist.



Normal anatomy of the hand and wrist in the posteroanterior *(A)* and lateral *(B)* projections.

Fractures – Classification and Complications.

Classification of fractures

A fracture refers to a break in the structural continuity of the bone.

The fractured bone heals by a complex process of bone repair. Complications can arise both as a result of the inciting trauma, as well as during the healing process.

Fractures may be broadly classify into

- complete – the bone is completely broken into 2 or more fragments
- incomplete – only one side of the bone is broken

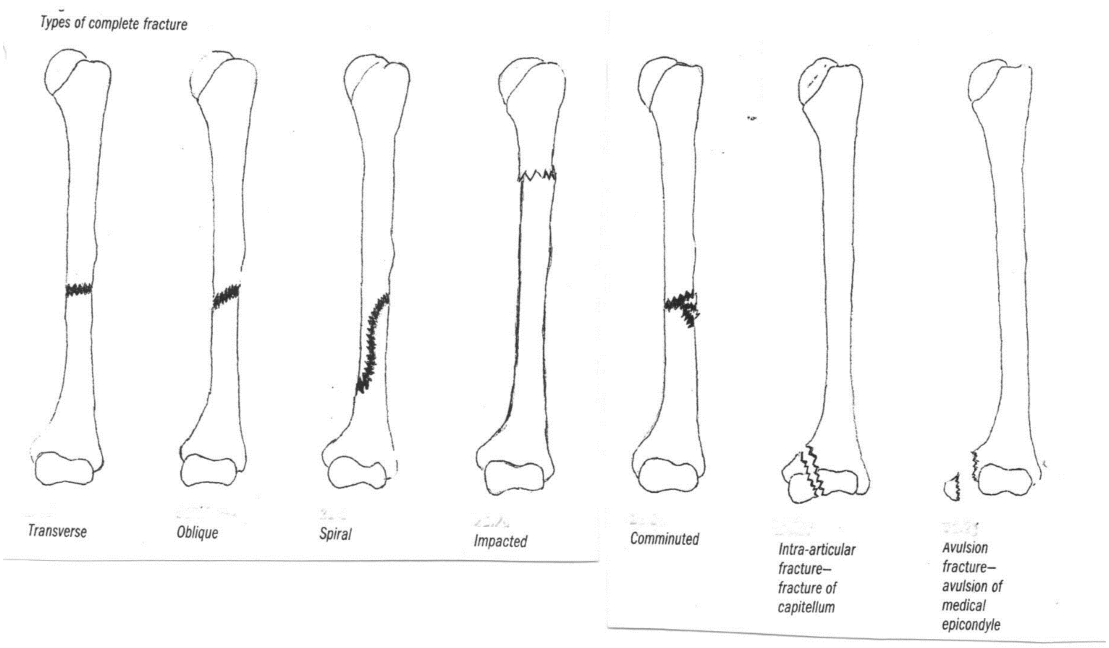
Further classification of complete fractures –

- Transverse fractures
- Oblique / spiral fractures
- Impacted fractures
- Comminuted fractures
- Intra-articular fractures

Incomplete fractures –

- Greenstick fractures – normally seen in children
- Compression fractures in adults

An avulsion fractures occurs when a fragment of bone is torn away from the rest of the bone due to a pull of a strong ligamentous of tendinous attachment.



Complications

Complications arising from fractures may be systemic or localised to the fractures bone, adjacent soft tissue or joints.

Local complications involving bone:

- Complications of union – delayed union
  - Non-union
  - Malunion
- Infection
- Avascular necrosis – occurs when the bone dies due to lack of blood supply. The fracture fails to unite and the ischemic bone may collapse. This typically manifests radiographically as areas of rarefaction and sclerosis. Certain fractures are particularly associated with avascular necrosis, like
  - Femur neck fracture (avascular necrosis in femur head)
  - Scaphoid waist (avascular necrosis in proximal fracture fragment)
  - Talus neck (talus body)
  - Humerus neck (humerus head)

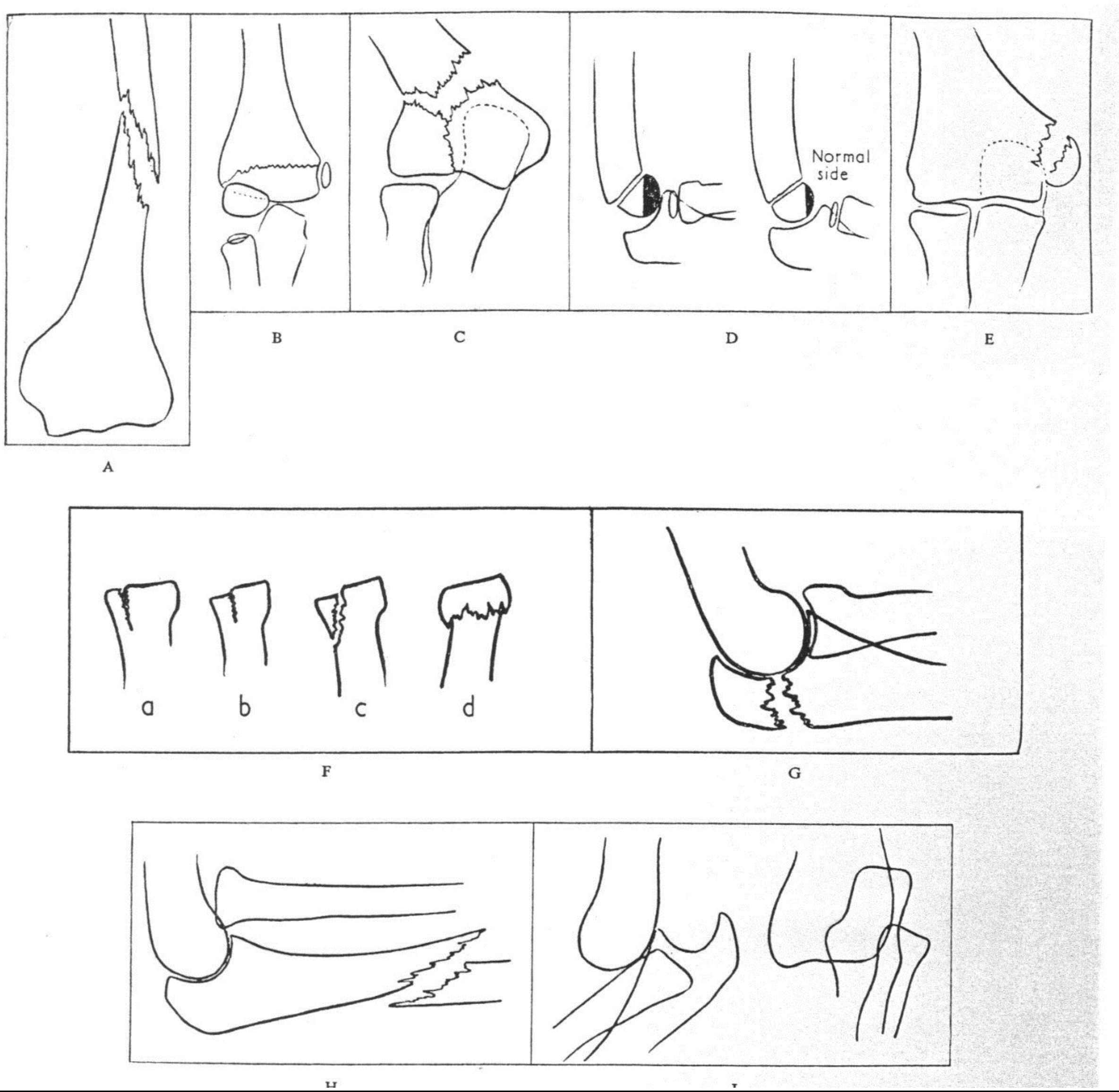
Trauma to the Elbow

Trauma to the elbow is commonly encountered in all age groups.

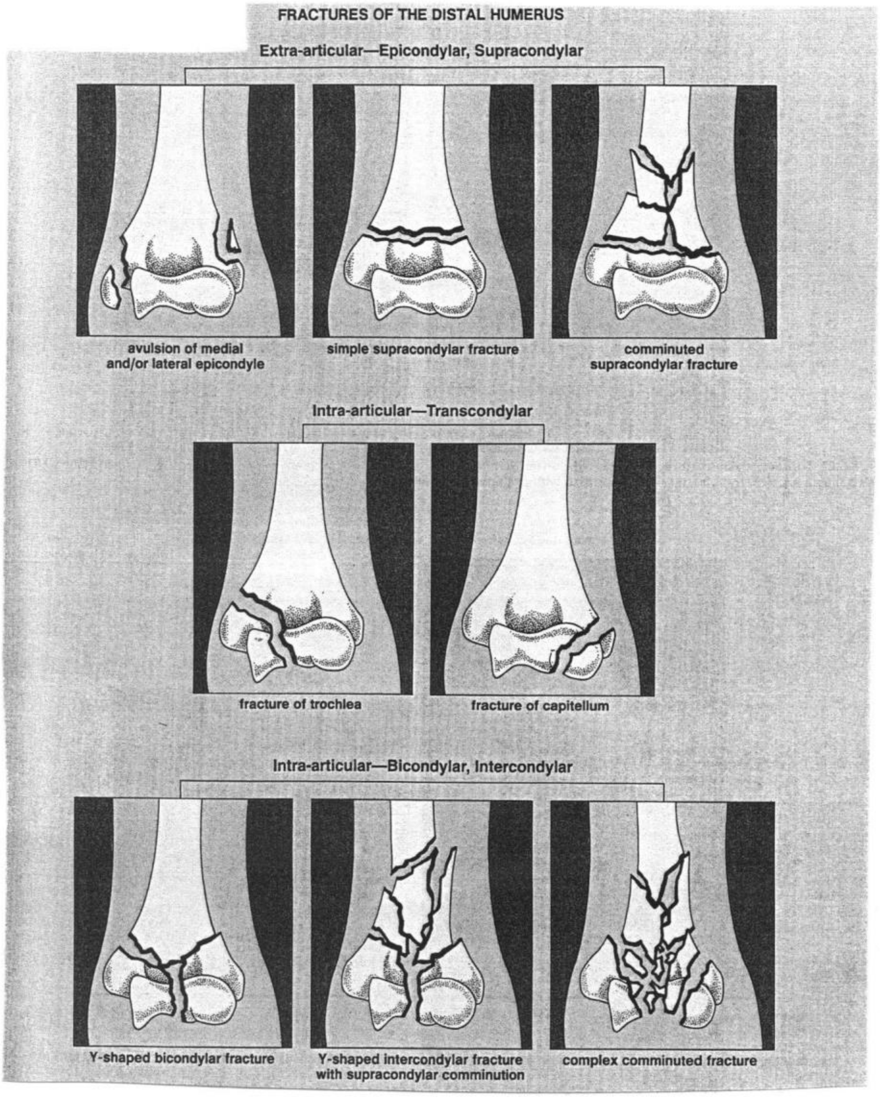
Although history and clinical examination usually provide clues to the correct diagnosis, radiological examination is indispensible in determining

- The type of fracture or dislocation
- The direction of the fracture line
- The position of the fragments
- And evaluating concomitant soft tissue injuries

Fractures about the elbow



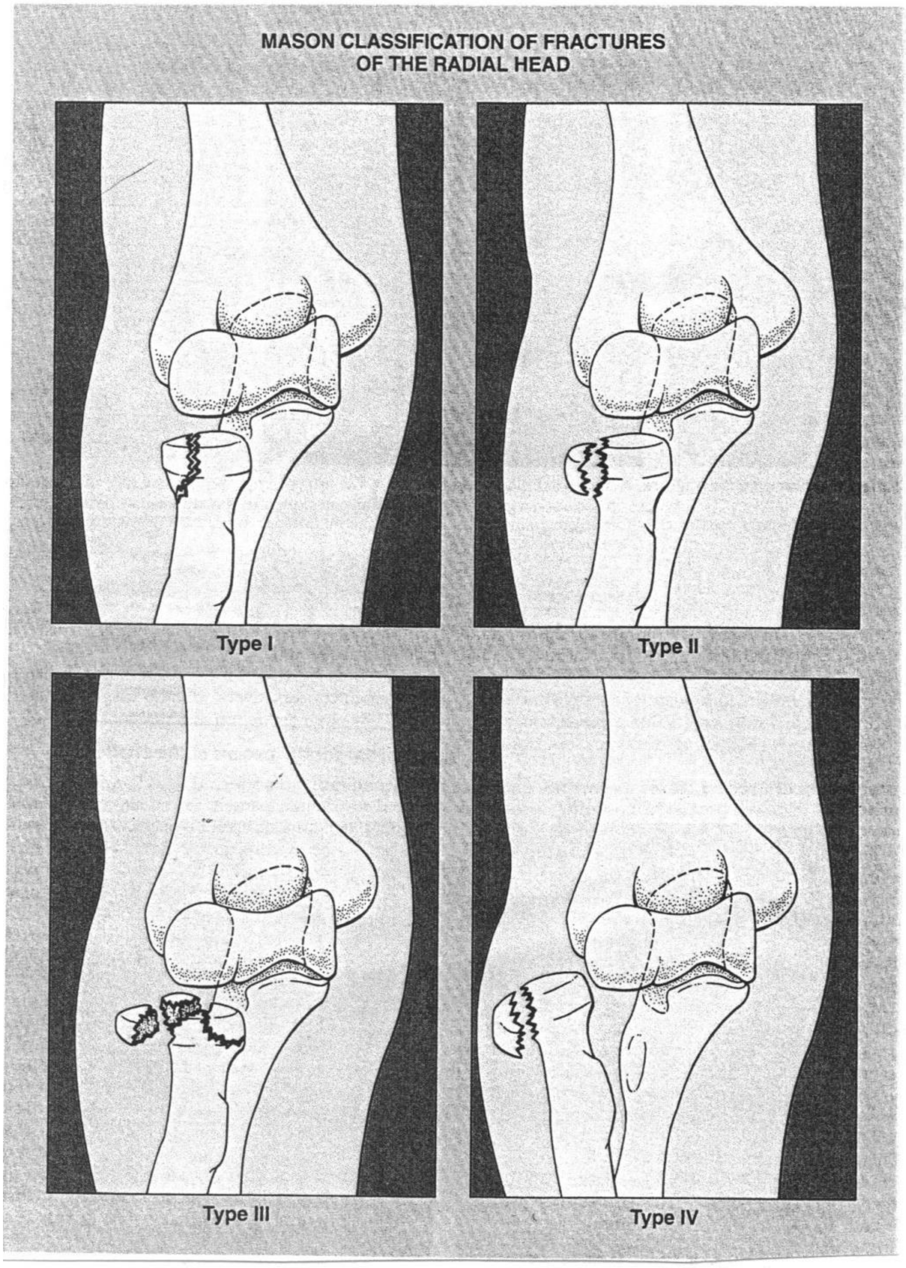
Fractures of the distal humerus –



Usually, fractures of the distal humerus pose no diagnostic problems in adults (children will be discussed in another session) and are readily evaluated on the anterioposterior and lateral projections of the elbow. Only occasionally may a CT scan be requested to localise comminuted fragments.

It is important in a fracture of the distal humerus to demonstrate and evaluate fully the type of injury, the extension of the fracture line, and the degree of displacement, because the method of treatment varies accordingly. A complication of a fracture of the distal humerus can be malunion, which can lead to a deformity of the elbow.

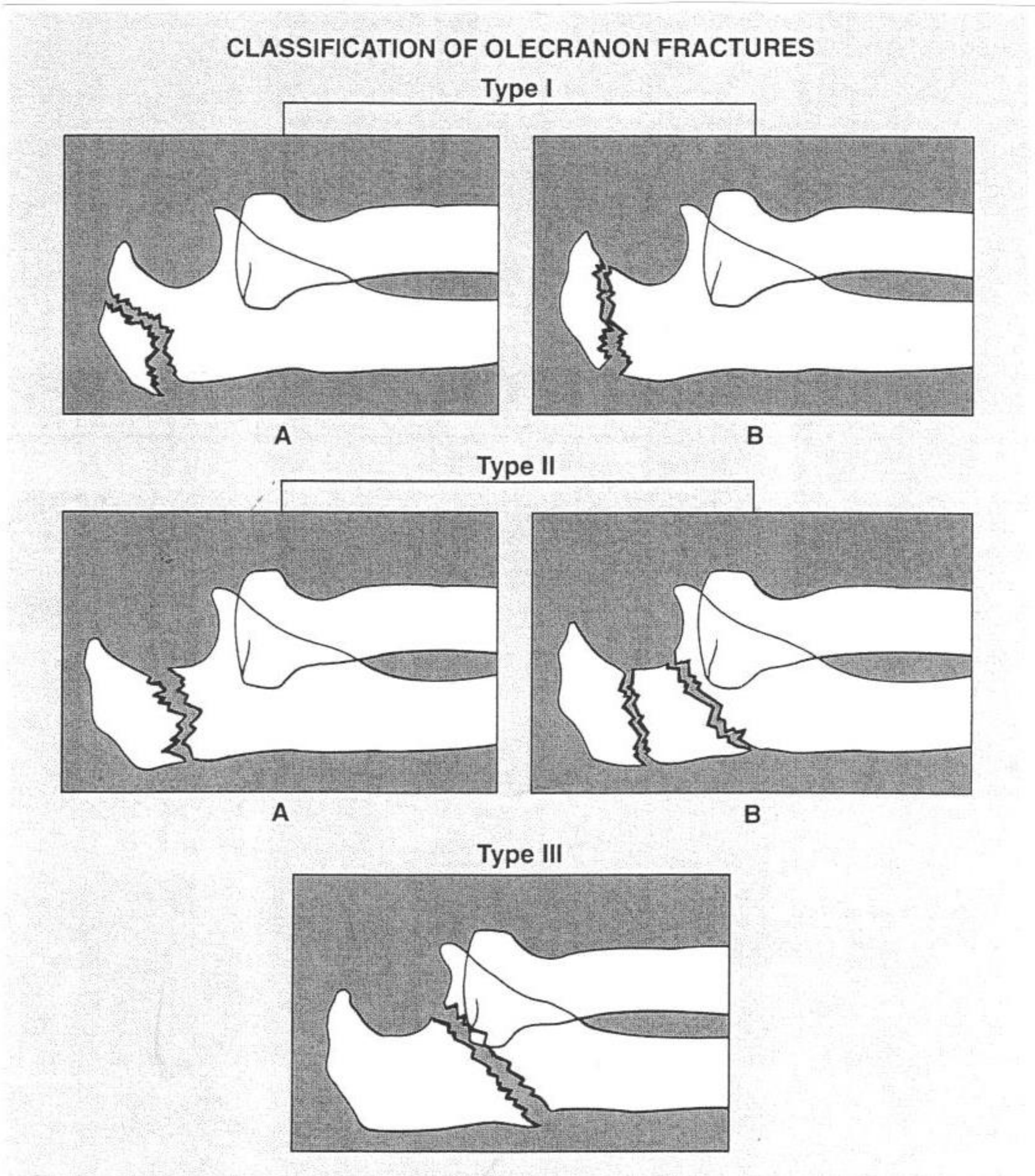
Fractures of the radial head –



Fractures of the radial head is a common injury that results, in most cases, from a fall on the outstretched arm and, only rarely, from a direct blow to the lateral aspect of the elbow.

Most fractures of the radial head can be adequately demonstrated on the anterioposterior and lateral projections of the elbow. Determination of the exact extension of the fracture line (whether it is extra-articular or intra-articular) and the degree of misplacement is crucial to deciding the course of treatment. CT examination plays an important role in this assessment. Treatment can range from conservative splints or casts to open reduction and internal fixation to excision of the radial head.

Fracture of the olecranon –



Olecranon fractures usually result form a direct fall on the flexed elbow, and this mechanism frequently produces comminution and marked displacement of the major fragments. An indirect mechanism, like a fall on the outstretched arm, produces an oblique or transverse fracture with minimal displacement. The fracture is usually well demonstrated on a lateral projection of the elbow.

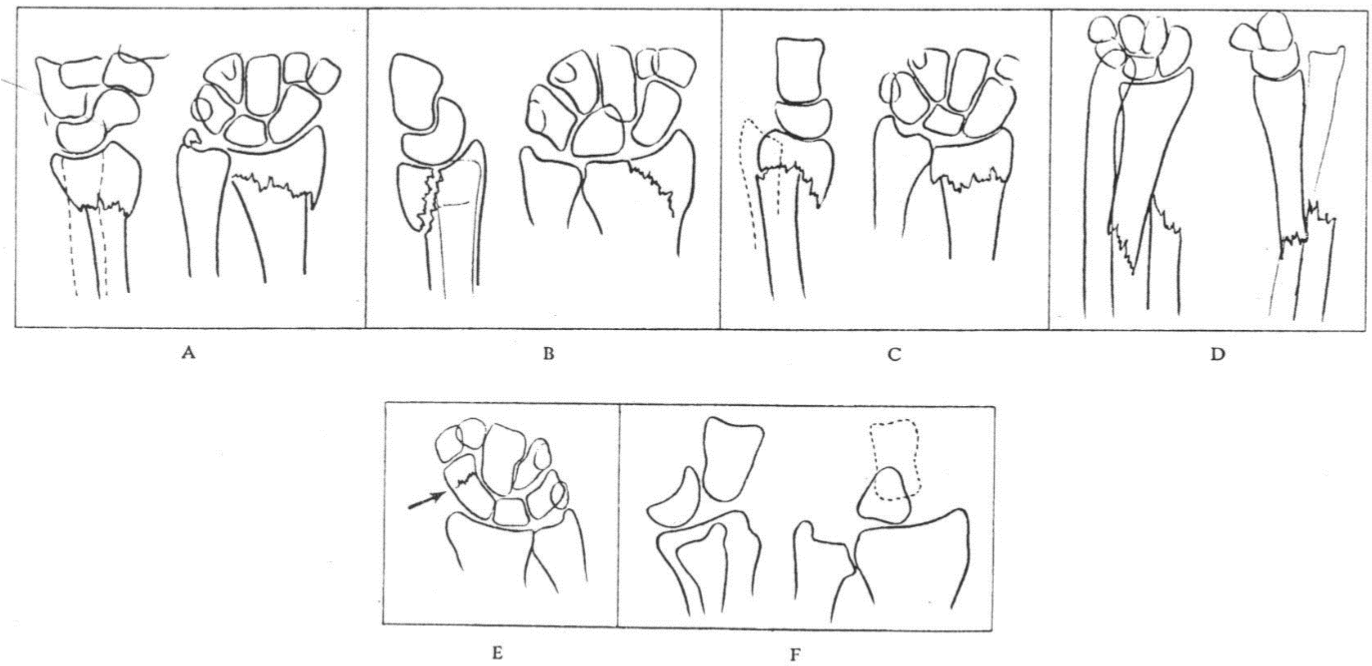
As far as treatment is concerned, non-displaced fractures are usually treated conservatively, whereas displaced fractures are most often treated by open reduction and internal fixation.

Trauma to the Forearm and Wrist.

Injury to the distal forearm, caused predominantly (90% of cases) by a fall on the outstretched hand, is common throughout life but is most common in the elderly.

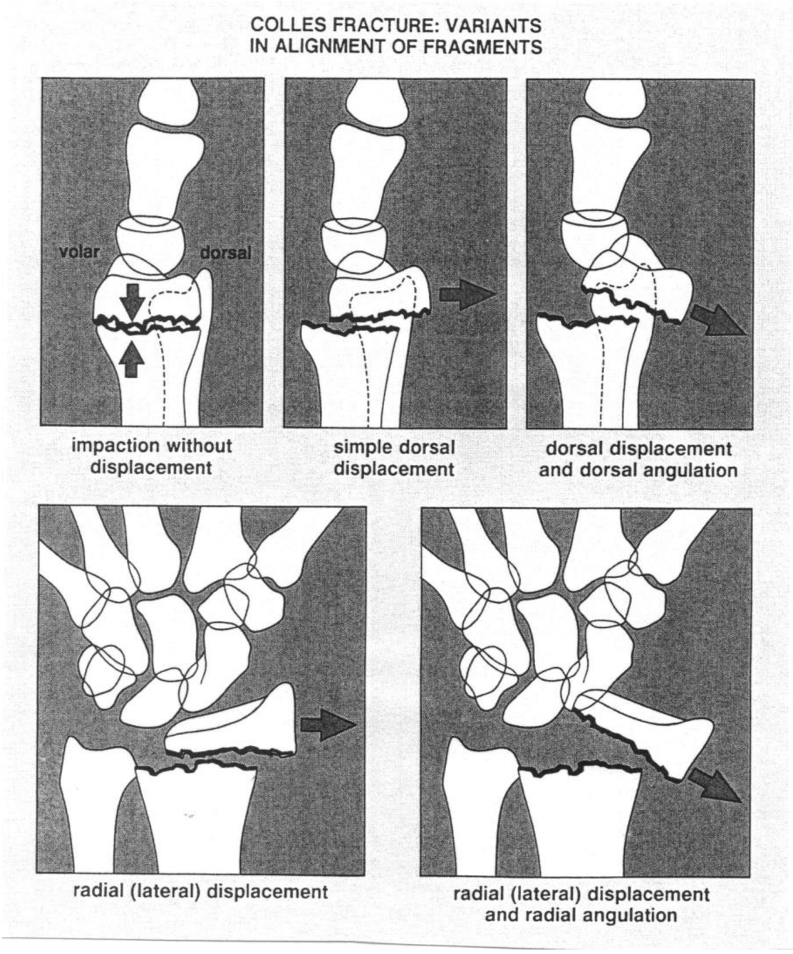
The type of injury usually sustained is fracture of the distal radius and ulna, the incidence of which substantially exceeds that of dislocation in the distal radio-ulnar and radio-carpal articulations.

Although history and a physical examination usually provide important information regarding the type of injury, radiographs are indispensible in determining the exact site and extent; in several types of fractures, only adequate radiographic examination can lead to the correct diagnosis.



Fractures of the distal radius –

Colles fracture



The most frequently encountered injury to the distal forearm, Colles fracture, usually results from a fall on the outstretched hand with the forearm pronated in dorsiflexion. It is most commonly seen in adults older than the age of 50 years and more often in women than in men.

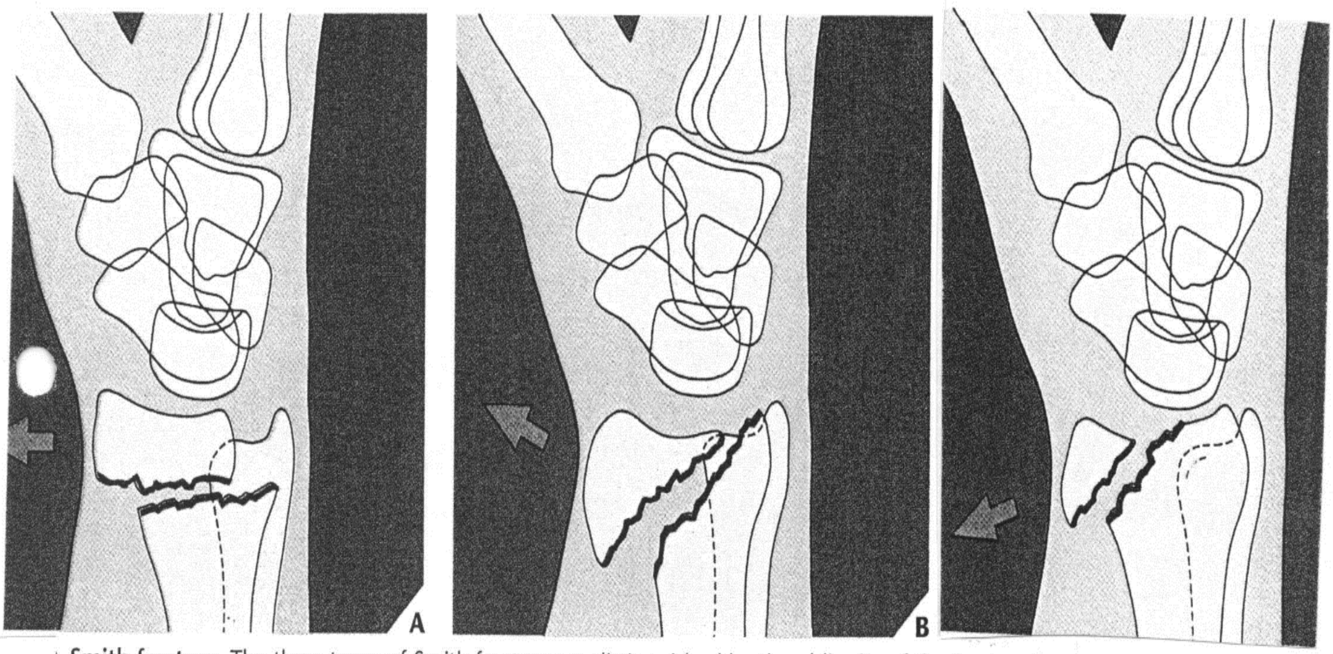
The fracture line is extra-articular, usually occurring 2 to 3 cm from the articular surface of the distal radius. In many cases, the distal fragment is radially and dorsally displaced and shows dorsal angulation, although other variants in the alignment of the fragments may also be seen. Commonly, there is an associated fracture of the ulnar styloid process.

Radiographs in posterioanterior and lateral projections are sufficient to demonstrate a Colles fracture. CT scanning may provide additional information concerning the exact position of displaced fragments.

A complication is that at the time of fracture, concomitant injury to the median and ulnar nerves may occur.

Fractures of the distal radius –

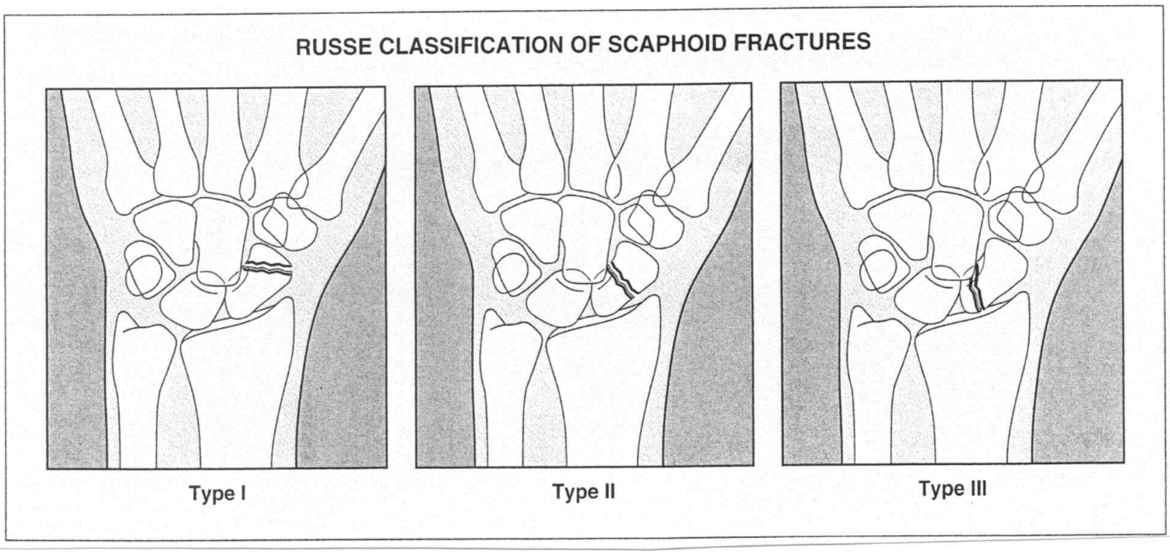
Smith fracture



Smith fracture. The three types of Smith fracture are distinguished by the obliquity of the fracture line.

Usually resulting from a fall on the back of the hand or a direct blow to the dorsum of the hand in palmar flexion, a Smith fracture consists of a fracture of the distal radius, which sometimes extends into the radio-carpal joint, with anterior (volar) displacement and angulation of the distal fragment. Because of the deformity in this fracture is the opposite of that seen in a Colles injury, it is often referred to as a reverse Colles fracture; it is however much less common than Colles.

Fracture of the scaphoid bone –



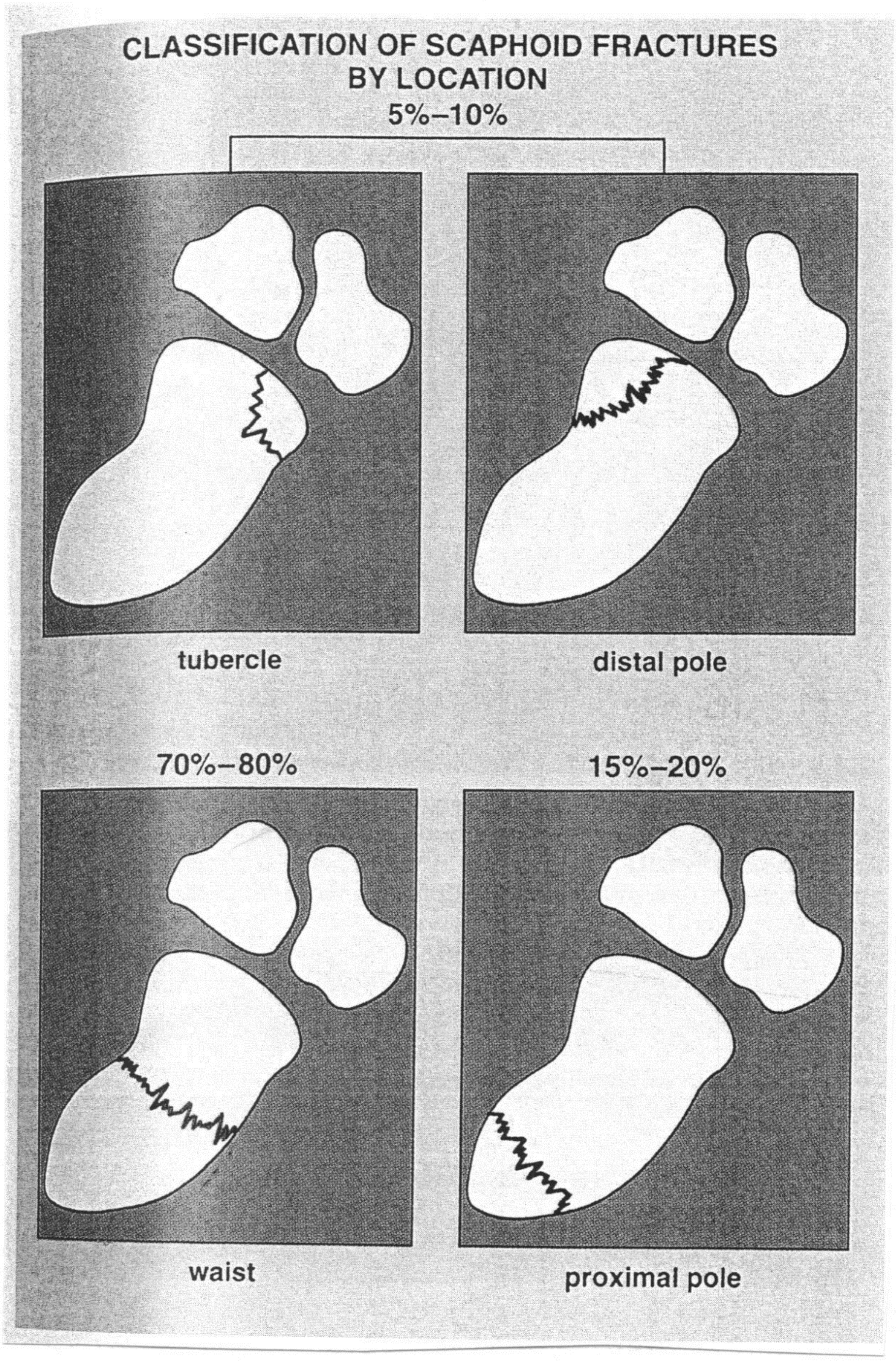
Fractures of the scaphoid are the second most common injuries of the upper limb, exceeded in frequency only by fractures of the distal radius. Of all fractures and dislocations in the carpus, this fracture is the most common, accounting for 50% to 60% of such injuries. They frequently occur in young adults (ages 15 to 30 years) after falls on the outstretched palm of the hand.

Fractures of the tuberosity (extra-articular) and distal pole of the scaphoid usually result from direct trauma and rarely cause any significant clinical problems. Fractures of the waist of the scaphoid, if there is no displacement or carpal instability, display a good healing pattern in more than 90% of cases. Fractures involving the proximal pole have a high incidence of non-union and osteonecrosis.

When a fracture of the scaphoid is suspected, standard radiographs usually suffice to demonstrate any abnormality. However, CT and MR imaging can be done to diagnose subtle fractures and to detect various complications.

Complications: delayed diagnosis and consequently delayed treatment of scaphoid fracture may lead to complications such as non-union, osteonecrosis and posttraumatic arthritis, the first two of which are the most commonly seen. Osteonecrosis usually affects the proximal fragment and only rarely the distal pole because of the good supply of blood to this part of the bone. Osteonecrosis most frequently becomes apparent 3 to 6 months after the injury when the affected fragment shows evidence of increased density. Patients with delayed union or non-union are more prone to osteonecrosis.

Non-union is usually treated surgically by bone grafting and if this approach fails, then the scaphoid may be excised and replaced by prosthesis.



Notes complied from

Tortora, G.J. & Derrickson, B. 2011. *Principles of Anatomy and Physiology*. 13th ed. Asia: John Wiley & Sons.

ADDENDUM D: PRE-TEST AND POST-TEST

Student name:

ANATOMY 1.

Traumatic injuries of the elbow and wrist.

Pre-test (same for post-test) – 20 minutes 6 September 2012

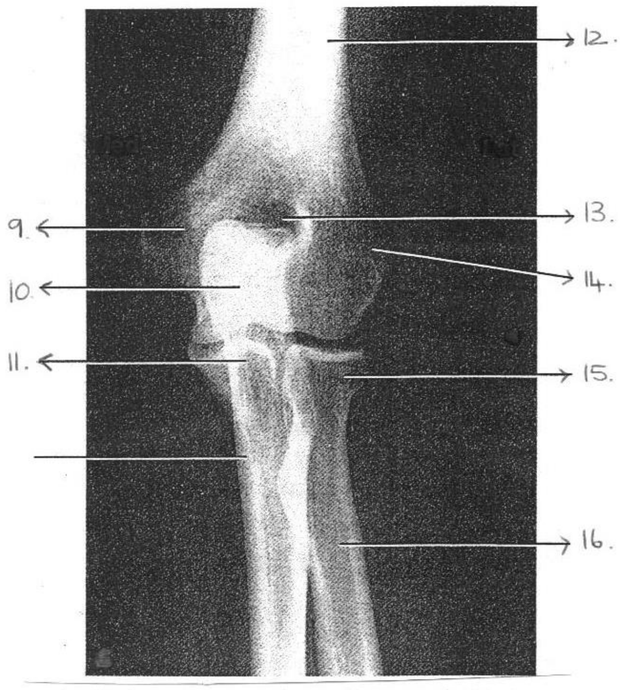
Please select one possible answer to the question.

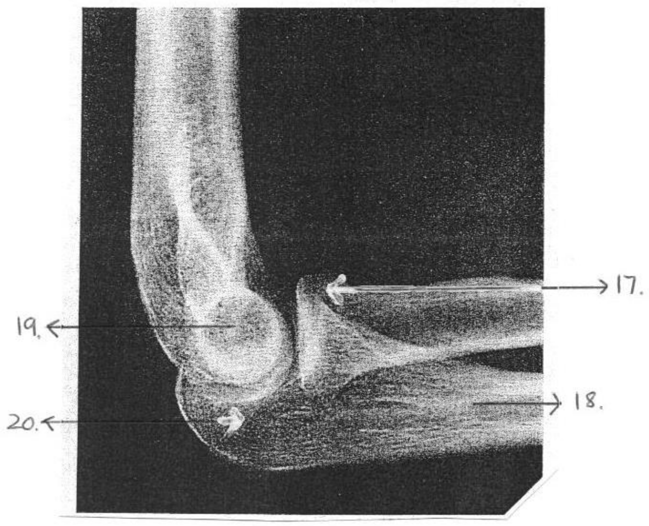
Elbow

1. The capitulum of the humerus articulates with
   a. The trochlea
   b. The radius
   c. The ulna
2. Superior to the trochlea and capitulum on the posterior distal humerus, lies
   a. The coronoid fossa
   b. The radial fossa
   c. The olecranon fossa
3. It projects anteriorly from the proximal end of the ulna
   a. The olecranon
   b. The coronoid process
   c. The ulnar tuberosity
4. The muscle at the back of the humerus is the
   a. Brachialis
   b. Triceps brachii
   c. Biceps brachii
5. If the humerus is fractured, which nerve may become stretched of transacted and may lead to permanent damage and loss of function?
   a. The ulnar nerve
   b. The median nerve
   c. The radial nerve
6. The proximal radio-ulnar joint, is a joint between
   a. The radius head and radial notch of the ulna
   b. The radial neck and the ulnar tuberosity
   c. The radial tuberosity and the radial notch of the ulna

7. Which nerve passes posterior to the medial epicondyle of the humerus?
    a. The radial nerve
    b. The medial nerve
    c. The ulnar nerve
8. What is the fracture of the distal humerus just above the elbow called?
    a. A spiral fracture
    b. An avulsion fracture
    c. A supracondylar fracture

You are supplied with normal anterio-posterior and lateral views of an elbow. Please label as marked.





9.
    a. Lateral epicondyle
    b. Medial condyle
    c. Medial epicondyle
10.
    a. Coronoid process
    b. Olecranon
    c. Trochlea
11.
    a. Coronoid process
    b. Ulna
    c. Olecranon fossa
12.
    a. Humerus
    b. Radius
    c. Ulna
13.
    a. Trochlear notch
    b. Olecranon fossa
    c. Capitulum
14.
    a. Lateral epicondyle
    b. Medial epicondyle
    c. Lateral condyle
15.
    a. Ulnar tuberosity
    b. Radial head
    c. Coronoid process
16.
    a. Radius
    b. Ulna
    c. Radial notch
17.
    a. Coronoid process
    b. Capitulum
    c. Radial head
18.
    a. Humerus
    b. Ulna
    c. Radius

19.

a. Trochlea
b. Capitulum
c. Coronoid process

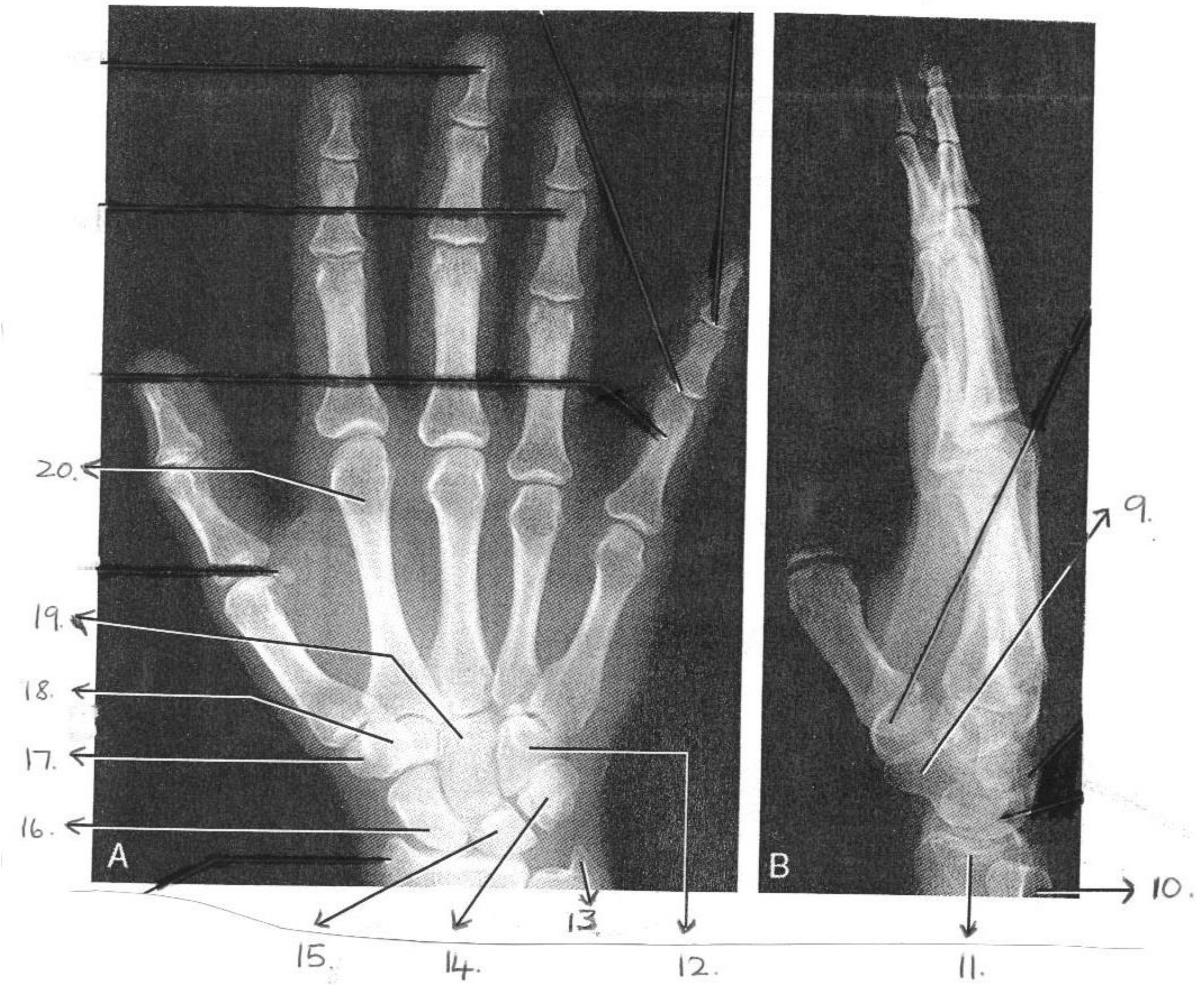
20.

a. Olecranon
b. Capitulum
c. Troclear notch

Wrist

1. The distal radio-ulnar joint occurs between
   a. The ulnar head and the ulnar notch on the radius
   b. The ulnar styloid process and radial notch
   c. The ulna and radial styloid process
2. The medial and lateral borders of the radius and ulna are connected by
   a. A bibrous articular disc
   b. The interosseous membrane
   c. The periosteum
3. The largest carpal bone is
   a. The lunate
   b. The scaphoid
   c. The capitates
4. Which carpal bones articulate with the radius?
   a. Triquetrum and lunate
   b. Scaphoid and lunate
   c. Triquetrum and pisiform
5. What forms the anterior wall of the carpal tunnel?
   a. Flexor retinaculum
   b. Flexor carpi ulnaris tendon
   c. Anconeus
6. Which artery passes through the anatomical snuffbox?
   a. Ulnar artery
   b. Radial artery
   c. Brachial artery
7. A Colles fracture is
   a. A fracture of the distal radius with dorsal displacement
   b. A fracture of the distal radius with palmar displacement
   c. A fracture of the distal ulna with no displacement
8. An associated fracture with a Colles fracture is
   a. From the ulnar styloid process
   b. From the radial styloid process
   c. From the ulna

You are supplied with normal posterioanterior and lateral views of the wrist and hand. Please label as marked.



You are supplied with normal posterioanterior and lateral views of the wrist and hand. Please label as marked.

9.
    a. Trapezium
    b. Scaphoid
    c. Lunate

10.
    a. Radius
    b. Ulna
    c. Humerus

11.
   a. Ulna
   b. Humerus
   c. Radius
12.
   a. Hamate
   b. Capitatum
   c. Pisiform
13.
   a. Radial styloid process
   b. Sesamoid bone
   c. Ulnar styloid process
14.
   a. Triquetrum
   b. Lunate
   c. Pisiform
15.
   a. Pisiform
   b. Lunate
   c. Triquetrum
16.
   a. Trapezium
   b. Scaphoid
   c. Capitates
17.
   a. Trapezium
   b. Scaphoid
   c. Trapezoid
18.
   a. Trapezium
   b. Scaphoid
   c. Trapezoid
19.
   a. Hamate
   b. Trapezium
   c. Capitates

20.
   a. 4th metacarpal
   b. 2nd metacarpal
   c. Proximal phalanx

ADDENDUM E: READINESS ASSURANCE TESTS – IRAT AND GRAT

Student name or group:

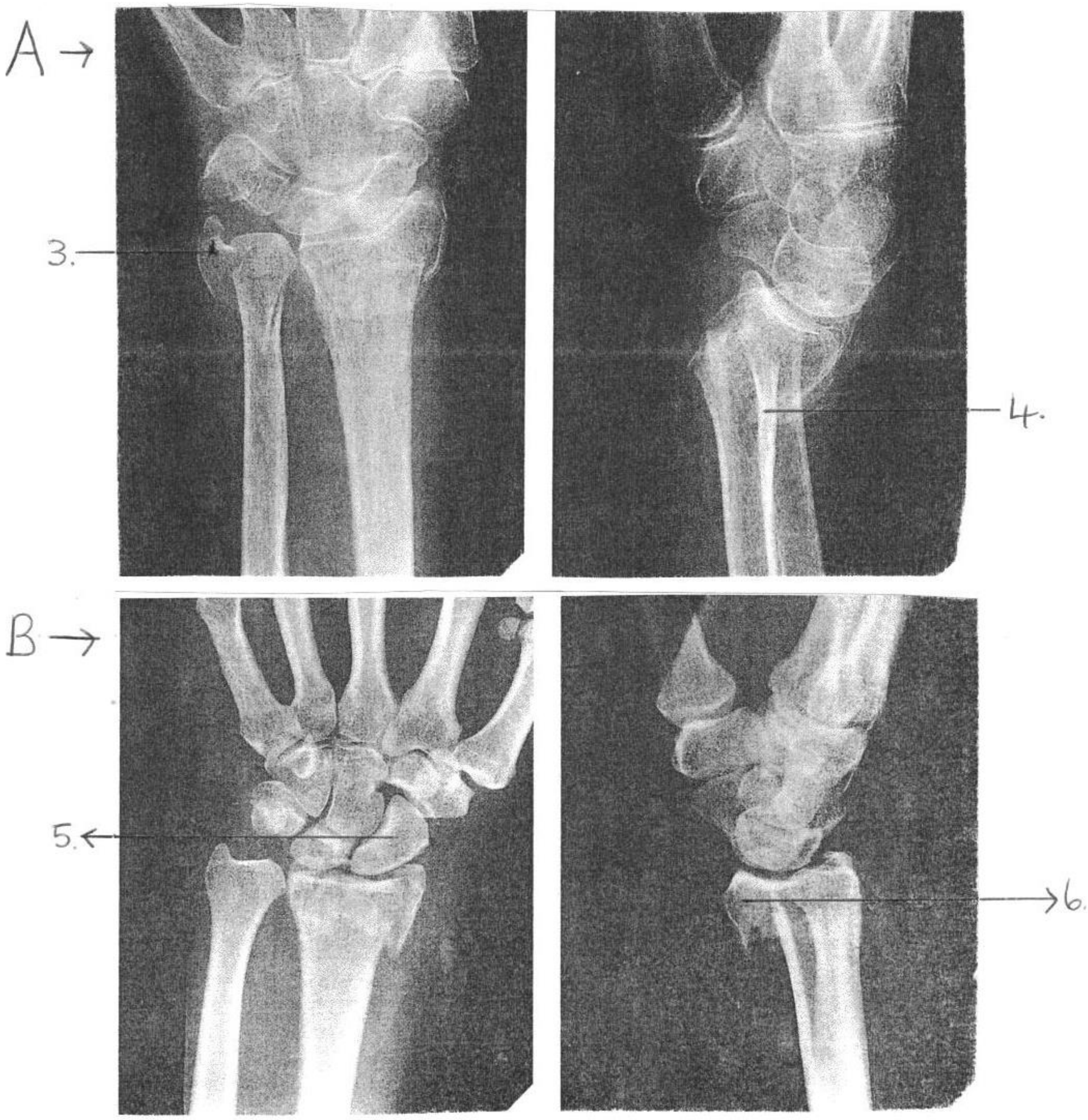
Anatomy 1

Traumatic injuries of the wrist

RAT – IRAT and GRAT 6 September 2012

Case study 1

You are supplied with two sets of posterior-anterior and lateral view x-rays of two different patients, marked A and B.



1. Films from patient A represent a
    a. Smith fracture
    b. Colles fracture
    c. Barton fracture
2. Films from patient B represent a
    a. Smith fracture
    b. Colles fracture
    c. Barton fracture

Patient A's films – please label as marked.

3.
    a. Ulnar styloid process
    b. Radial styloid process
    c. Pisiform
4.
    a. Radius
    b. Ulna
    c. Scaphoid

Patient B's films – please label as marked.

5.
    a. Scaphoid
    b. Lunate
    c. Capitates
6.
    a. Ulna
    b. Radius
    c. Scaphoid

Case study 2

A 13-year old boy fell from his bicycle on his hand.

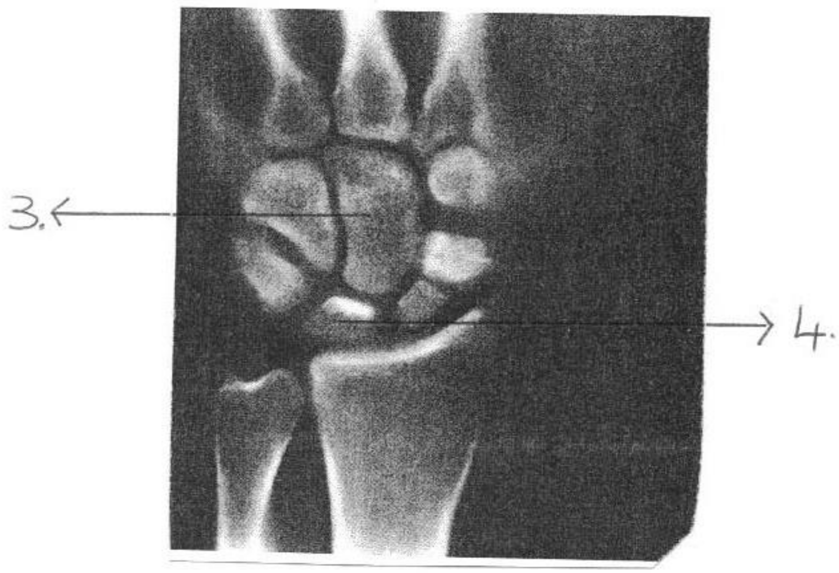
A radiograph of both his wrists is attached.

1. Which bone is fractured?
   a. Radius
   b. Ulna
   c. Scaphoid

Case study 3

A 40-year old man sustained a fracture of the scaphoid, which was treated by immobilisation for three months.

A posterior-anterior view of the right wrist is attached.



1. Where is the scaphoid fractured?
    a. The proximal pole
    b. The distal pole
    c. The waist
2. Which part is suspected of osteonecrosis?
    a. The proximal pole
    b. The distal pole
    c. The waist

Please label as marked.

3.
    a. Capitates
    b. Lunate
    c. Hamate
4.
    a. Capitates
    b. Lunate
    c. Hamate

Student name or group:

Anatomy 1

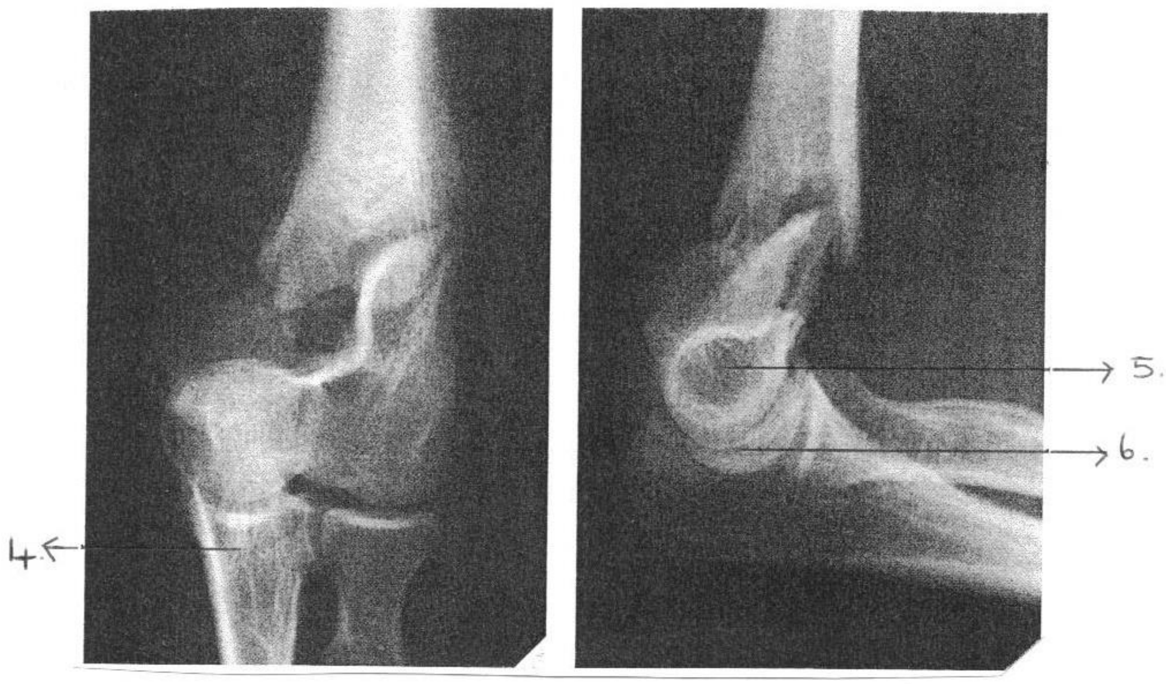
Traumatic injuries of the elbow

RAT – IRAT and GRAT 6 September 2012

Case study 1

A 27-year old man fell from a ladder and onto his outstretched arm and caused a displaced fracture.

Anterioposterior and lateral view x-rays of the elbow are attached.



Please select one best possible answer to the question.

1. Which bone is fractured?
    a. Right humerus
    b. Left humerus
    c. Left ulna
2. This fracture can be classified as a
    a. Spiral fracture
    b. A supracondylar fracture
    c. An avulsion fracture

3. In which direction is the distal bone fragment displaced?
    a. Anterior
    b. Posterior
    c. Medially

Please name the anatomy as labelled on the x-rays.

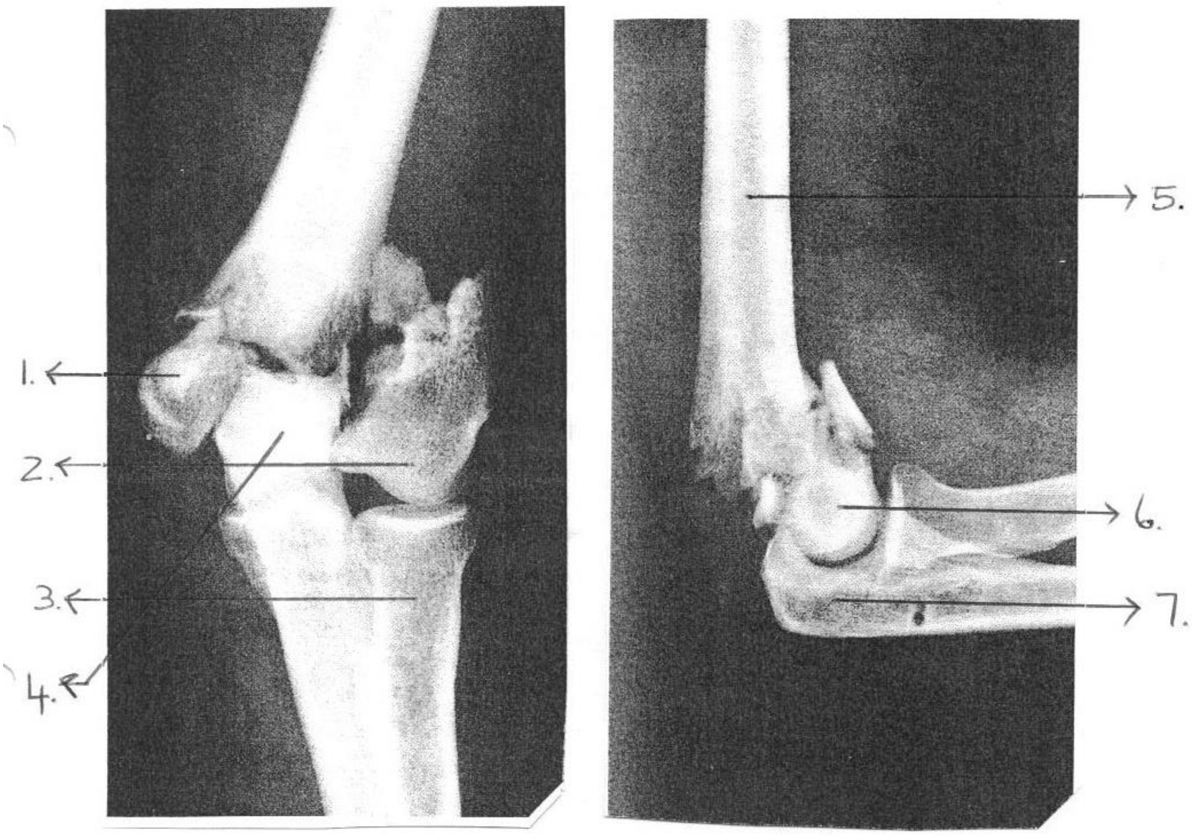
4.
    a. Humerus
    b. Ulna
    c. Radius
5.
    a. Capitulum
    b. Coronoid process
    c. Radial head
6.
    a. Olecranon
    b. Trochlea
    c. Trochlear notch

Case study 2

A 25-year old man sustained a complex intra-articular fracture of the distal humerus in a motorcycle accident.

Anterio-posterior and lateral view x-rays are attached.

Please name as labelled.



1.
    a. Lateral epicondyle
    b. Medial epicondyle
    c. Capitulum
2.
    a. Capitulum
    b. Medial epicondyle
    c. Trochlea
3.
    a. Ulna
    b. Radius
    c. Humerus

4.
  a. Trochlear notch
  b. Olecranon
  c. Radial notch

5.
  a. Radius
  b. Ulna
  c. Humerus

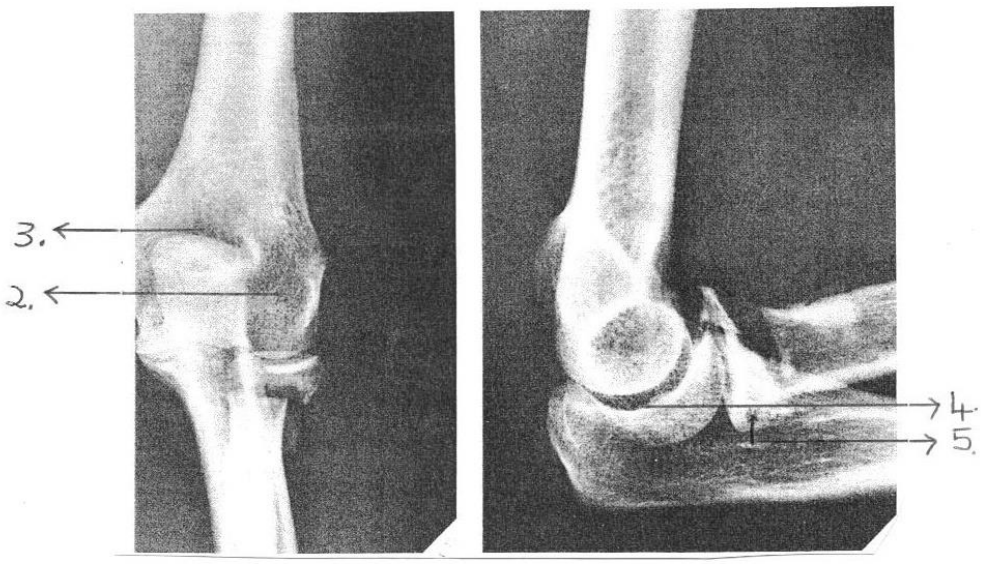
6.
  a. Capitulum
  b. Trochlea
  c. Trochlear tuberosity

7.
  a. Capitulum
  b. Trochlea
  c. Olecranon

Case study 3

A 52-year old woman fell on her arm and has a painful elbow.

Anterio-posterior and lateral view x-rays of the elbow are attached.



1. Which bone is fractured?
    a. The ulna
    b. The radius
    c. The humerus

Please label as marked.

2.
    a. Lateral epicondyle
    b. Oleranon fossa
    c. Medial epicondyle
3.
    a. Olecranon
    b. Trochlea
    c. Olecranon fossa
4.
    a. Trochlear notch
    b. Capitulum
    c. Oleranon
5.
    a. Radial head
    b. Trochlear notch
    c. Olecranon

Case study 4

A 52-year old woman fell on her outstretched arm.

A lateral view x-ray of the elbow is attached.

1. Which bone is fractured?
   a. Ulna
   b. Radius
   c. Humerus

Please name as labelled.

2.
   a. Olecranon
   b. Capitulum
   c. Radius

ADDENDUM F: FEEDBACK QUESTIONNAIRE

Anatomy 1

Student feedback on a team-based learning activity

Thank you for participating in the feedback, I appreciate your input!

Please tick the most appropriate answer in the column.

	1 Strongly disagree	2	3	4	5 Strongly agree
1. The team-based learning (TBL) exercise has improved my understanding of trauma to the elbow.					
2. I have been challenged to apply factual knowledge in solving a clinical problem during TBL.					
3. The contributions of the other students in my group have helped me learn during TBL.					
4. The contributions of the lecturer have helped me learn during TBL.					
5. The TBL has been a productive use of my time.					
6. I feel TBL activities are enjoyable.					

Adapted from Koles, Nelson, Stolfi, Parmelee and DeStephen (2008)

Please add any comments (positive or negative).